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# Climate Information Services in Southeast Asia: A Systematic Review

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## ABSTRACT

*Over the years, climate change has unraveled more issues that have affected the agricultural sector, most especially the already vulnerable smallholder farmers who have borne the burden of intensifying climate impacts. Given this urgent matter, the need to prioritize climate services for science-based decision-making and strategic planning has been more pertinent than ever. This paper scrutinizes the type of climate services available to Southeast Asian smallholder farmers and the role these play in climate change adaptation. Guided by the PICoST (Population, Interest, Context, Scope, and Time) approach, only 22 materials published from 2015 to 2022 were identified from a systematic review of Google Scholar, ScienceDirect, and Web of Science (WoS) literature, reflecting a poverty of literature in Southeast Asia despite the region's high exposure to climatic hazards. From the review, disaster risk management was found to be the recurring theme in the collated literature. Further analysis revealed that smallholder farmers rely on both climate-related information (i.e., rainfall, temperature, wind, etc.) and advisories (i.e., forecasts on thunderstorms, droughts, tropical cyclones, etc.) to guide their farming activities. Findings of this review underscore the relevance of climate services as well as its localization and suggest the inclusion of traditional indicators in climate forecasting.*

Keywords: climate services, disaster risk management, informed decision-making, adaptation strategies, meteorological information

## INTRODUCTION

Regarded as the backbone of most economies, agriculture has always been integral in advancing economic development and food security (Loizou *et al*., 2019; Liu *et al*., 2020; Pawlak & Kołodziejczak, 2020), providing millions of poverty-stricken households with livelihood and sustenance (Cohn *et al.*, 2017). For Asia alone, the value of its agricultural production represents 51% of total world figures (Food and Agriculture Organization [FAO], n.d.). But with a region highly vulnerable to climate change, food availability and accessibility issues are expected to persist. Unless agricultural producers—most especially smallholder farmers—are prioritized and assisted to better cope with climate impacts, they will continue to bear the brunt of the climate crisis. Worse, this will be a major challenge not only to agriculture-dependent livelihoods but most especially to sustainably feed Asia's fast-growing population.

### State of agriculture and smallholder farming in Southeast Asia

Southeast Asia is endowed with rich natural resources which have been a source of food and livelihood for its people. Overall, Southeast Asian agriculture has contributed US$684 million (15.8% share) to the region's gross domestic product at US$4.3 billion in 2020. (FAO, n.d.-c). In the same year, some of the top commodities in the region are rice, oil palm fruit, sugar cane, cassava, maize, and coconuts.

Rice is a staple food of at least half of the global population (Hayashi *et al*., 2018), with 90% of the total production coming from Asia (Lin *et al*. 2022). Southeast Asia, in particular, contributes 25% to the world's rice supply (FAO, n.d.) and is home to five of the top ten rice-producing countries as seen in Figure 1. The heavy reliance on Asian rice supply has been seen as a global risk, especially because the region is historically being severely impacted by extreme weather events and disasters (Pulhin *et al*., 2021) which can disrupt production cycles and supply chain.

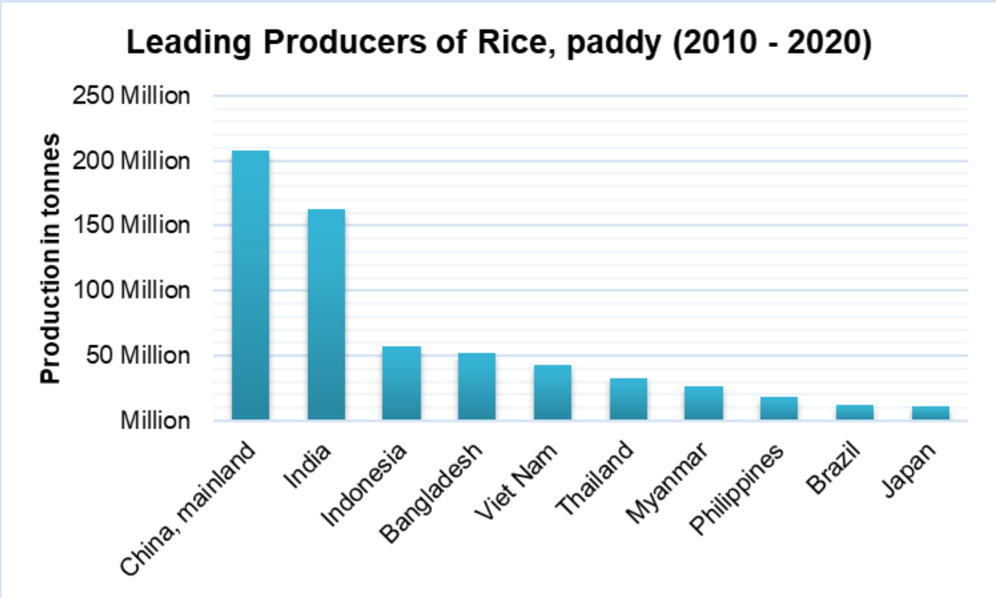



Figure 1. Top 10 producers of rice, paddy from 2010 to 2020 (FAO, n.d.-a).

Home to more than 600 million people, the 2019 International Labour Organization (ILO) model approximates that 30.48% of the total labor force is employed in agriculture, forestry and fishing (FAO, n.d.-b). At least 100 million small-holder farmers—producers with a cultivation area smaller than 2 ha (Lowder *et al.*, 2016)—is estimated to be residing in Southeast Asia (Mikolajczyk *et al.*, 2021) and they are considered to be the main players in the production of the region's top agricultural commodities.

Herrero *et al*. (2017) also underscored that small-holder farming in Sub-Saharan Africa, Southeast Asia, and South Asia supplied 30% of the food commodities in the region.

## Observed impacts of climate change

With the continuous variability and unpredictability of the climate, there is a consensus that climate change is one of the greatest threats to the agricultural sector (Mendelsohn, 2014; Cohn *et al*., 2017; Liu *et al*., 2020; Intergovernmental Panel on Climate Change [IPCC], 2022), which concurrently increases the risk of food insecurity due to the expanding global population (Malhi *et al*., 2021). Climate change, as highlighted by Liu *et al.* (2020), exacerbates the pressure on agricultural production by accelerating land degradation and limiting water supply with small-holder farmers receiving the brunt of its effects (Cohn *et al*., 2017; Nor Diana *et al*., 2022). Such impacts are projected to worsen as global warming intensifies (Malhi *et al*., 2021; IPCC, 2022), which will be discussed further in the succeeding passages.

While poverty of literature on the observed impacts of the changing climate persists, the nexus between climate change and agricultural production has been widely acknowledged (Tolentino & Landicho, 2013; Mendelsohn, 2014; IPCC, 2018; Liu *et al*., 2020; Malhi *et al*., 2021; IPCC, 2022). For instance, FAO (2021) reports that losses in the production of crops and livestock in Asia have reached up to US$49 billion from the period of 2008 to 2018, wherein 42% of the incurred losses (i.e., ~US$20.7 billion) were found in Southeast Asia. This is primarily attributed to geophysical disasters, floods, and storms, which accounted for approximately US$11.4 billion, US$11 billion, and US$10 billion, respectively (refer to Figure 2). With drought succeeding these disasters, it is important to note that the catastrophic effects of drought are primarily centered in the agricultural sector on a global scale (FAO, 2021).

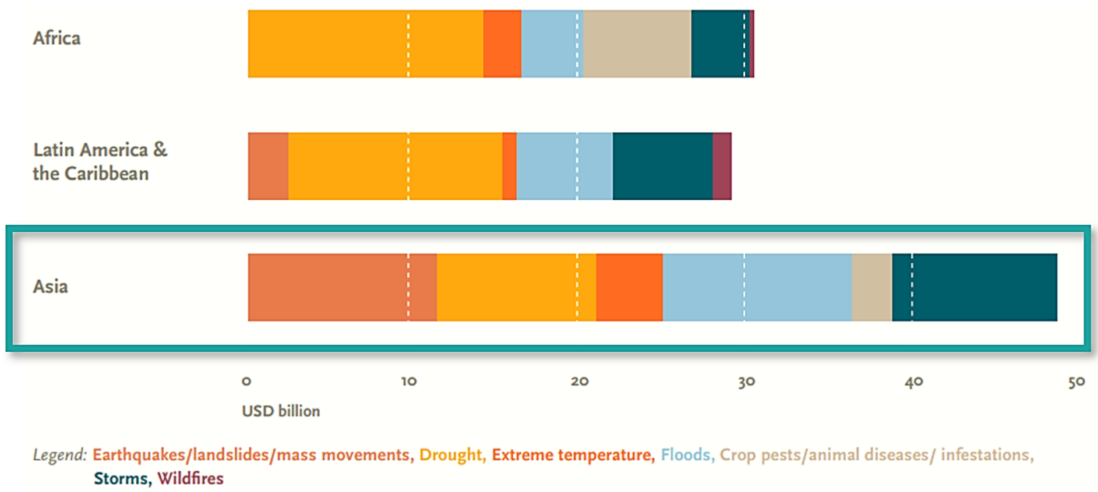



Figure 2. Total regional losses in crop and livestock production of low-middle-income and least developed countries per disaster from 2008 to 2018 (FAO, 2021).

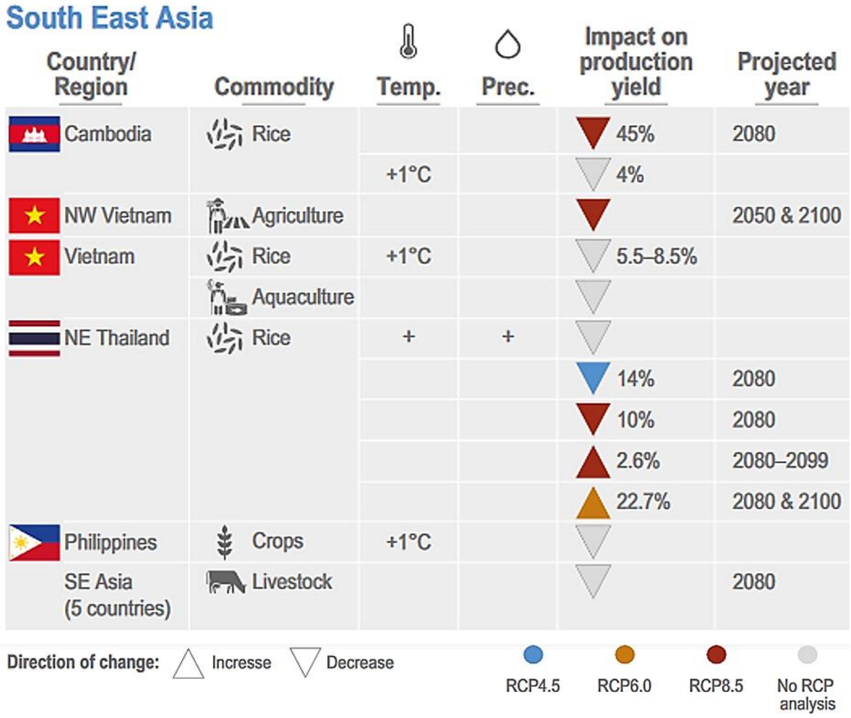
In recent years, Filipino and Indonesian farmers have been experiencing harvesting delays with lower quality and quantity of outputs, heightening cases of pests and diseases as well as mortality of livestock, which ultimately result in lower revenue (Tolentino & Landicho, 2013). In addition, incidences and intensity of El Niño strongly associated with the rising temperature have also led to significant losses in crop production (Thirumalai *et al*., 2017; Rifai *et al*., 2019). Irrigated and rainfed croplands in some countries in Southeast Asia (i.e., Cambodia, Indonesia, Laos, Myanmar, Thailand, and Vietnam) incurred 21.9 million tons worth of production losses during the 2015 to 2019 El Niño (Venkatappa *et al*., 2021). In terms of economic losses, almost 97% of the incurred losses in Southeast Asia have been recorded in Indonesia, Malaysia, Thailand, and Vietnam (Ha *et al*., 2022). The World Bank Group & Asian Development Bank (2021), on the other hand, reports that 84.2% of the losses in rice production during the 1970s were attributed to extreme weather events (i.e., typhoons, floods, and droughts) which hit the Philippines for the next two decades. In the case of Thailand, about 3% of the actual average rice yield was lost every decade from 1984 to 2013 in the Mun River Basin of Northeast Thailand due to changing climate, which is equivalent to less than 50kg per hectare (Prabnakorn *et al*., 2018).

Apart from these notable impacts, climate change can also indirectly affect agriculture through its influence on the proliferation of pests (Chandra *et al*., 2017; Malhi *et al*., 2021). For instance, crop losses attributable to pest infestations (i.e., snails, rats, and beetles) have increased following incidences of extreme weather events (Chandra *et al*., 2017). This has been re-echoed by the findings of Malhi *et al.* (2021), which underscored the association between climate-driven changes in temperature and humidity and the increased range of agricultural pests.

## Projected impacts of climate change

Given the present devastating effects of climate change on agriculture, evidences focusing on the exacerbation of its impacts has been compelling (Mendelsohn, 2014; IPCC, 2018; Thiault et al., 2019; Malhi *et al*., 2021; IPCC, 2022). A notable example of this case is the IPCC 1.5°C report (2018), which accentuated that an additional 0.5°C in global temperature from the 1.5°C target will adversely affect the net yield of cereal crops (i.e., maize, rice, wheat, etc.). Similarly, the study of Mendelsohn (2014) compared the projected net income from crop production between 1.5°C and 3°C global warming for 2100. Accordingly, his findings revealed that the incurred net losses will at least double as warming exceeds 1.5°C, which can reach up to ~US$195 billion annually (Mendelsohn, 2014).

Focusing on Southeast Asia, future projections showed disproportionate negative impacts on both agriculture and fisheries among tropical countries (Thiault *et al*., 2019), ultimately aggravating food insecurity in the region (Asia-Pacific Association of Agricultural Research Institution [APAARI], 2018; IPCC, 2018). The same findings have been reiterated in the latest IPCC report (2022), which reflected the uneven prospective consequences of climate change on crop production based on the synthesis of post-IPCC AR5 materials (refer to Figure 3). While certain nations may experience an increase in yield, any positive impact of climate change on plants (i.e., increased $CO_2$ intake of C3 plants) will be negated by its detrimental effects on crop productivity (Tang, 2019; Malhi *et al*., 2021).


**South East Asia**

| Country/ Region | Commodity | Temp. | Prec. | Impact on production yield | Projected year |
|---|---|---|---|---|---|
| Cambodia | Rice | | | ▼ 45% | 2080 |
| | | +1°C | | ▽ 4% | |
| NW Vietnam | Agriculture | | | ▼ | 2050 & 2100 |
| Vietnam | Rice | +1°C | | ▽ 5.5–8.5% | |
| | Aquaculture | | | ▽ | |
| NE Thailand | Rice | + | + | ▽ | |
| | | | | ▼ 14% | 2080 |
| | | | | ▼ 10% | 2080 |
| | | | | ▲ 2.6% | 2080–2099 |
| | | | | ▲ 22.7% | 2080 & 2100 |
| Philippines | Crops | +1°C | | ▽ | |
| SE Asia (5 countries) | Livestock | | | ▽ | 2080 |



Figure 3. Future impacts of climate change on agriculture and other food systems in Southeast Asia (IPCC, 2022). Representative Concentration Pathways (RCPs) reflect the prospective climate warming scenarios relative to the greenhouse emissions, wherein RCP4.5 and RCP6.0 refer to moderate emissions while RCP8.5 denotes high emissions.

## State of climate change adaptation in Southeast Asia

Since the signing of the 2015 Paris Agreement, the initiatives on climate change adaptation has been booming globally along with the growing recognition of climate change's irreversible consequences (IPCC, 2018; Dedicatoria & Diomampo, 2019; IPCC, 2022). With the exception of Singapore, all nations in Southeast Asia have developed a national strategy or action plan to mitigate the present and prospective impacts of climate change with agriculture as one of its priority sectors (Dedicatoria & Diomampo, 2019). Despite the context-specific design of these adaptation measures, Figure 4 synthesizes the six (6) strategies to improve the adaptation techniques in agriculture, which emerged from the current body of knowledge hinged on Asian experiences (IPCC, 2022).

Focusing on the third strategy, it highlights the role of climate services in adaptation, a novel yet thriving field (Jacob *et al*., 2019). Climate services, as defined by IPCC (2018), refers to information and products devised not only to convey knowledge on climate change but also to assist the decision-making and strategic planning toward climate action. Furthermore, the growing demand for evidence-based decision-making and planning for long-term adaptation have made the application of climate services more imperative than ever (Hewitt & Stone, 2021; Boon *et al*., 2022). Interestingly, the focus of climate services has been transitioning to climate adaptation with agriculture as one of the leading industries (Larosa & Mysiak, 2019). Nonetheless, the association between the use of climate information and the adaptation strategy adopted by smallholder farmers is still poorly understood, particularly in Southeast Asia. Overall, this paper seeks to fill in the gap by unraveling the available climate services to the smallholder farmers as well as the core purpose for its utilization.

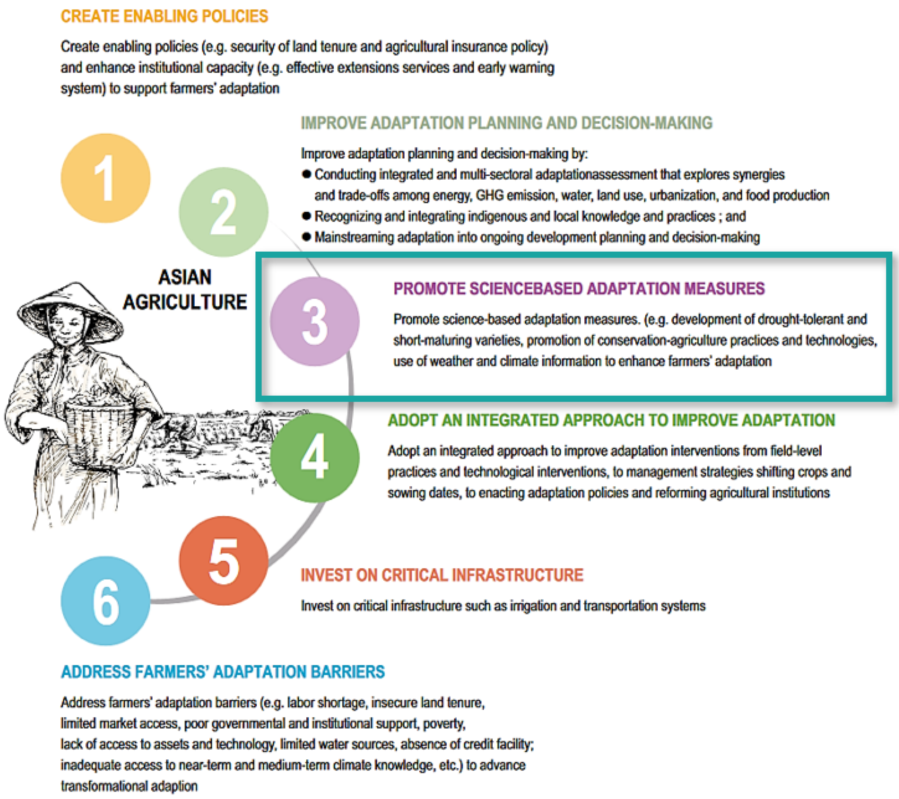



Figure 4. Strategies to advance current and future adaptations for the agricultural sector in Asia (IPCC, 2022).

## METHODOLOGY

To understand the role of climate services in adaptation relative to the climate change impacts on Southeast Asian small-holder farmers, a systematic review was adopted in identifying the pertinent literature for the analysis. Systematic review, as accentuated by Sirelkhatim & Gangi (2015), is an effective approach hinged on transparency and clarity for the synthesis of a large bulk of literature. Furthermore, it facilitates the thematic mapping and tracking of a continuously growing literature for a holistic analysis (Berrang-Ford *et al*., 2015; Sirelkhatim & Gangi, 2015), which is particularly relevant to the field of climate change adaptation (Berrang-Ford *et al*., 2015). Meanwhile, the Population, Interest, Context, Scope, and Time (PICoST) approach was utilized to define the boundaries of this review (refer to Table 1), which will be discussed further in the following passages.

Table 1. Key elements and coverage of the systematic review following the PICoST approach.

| PICoST Elements | Operationalized definition based on the review |
|---|---|
| Population (P) | Smallholder farmers in Southeast Asia |
| Interest (I) | Empirical evidence capturing the role of climate services in promoting resiliency of Southeast Asian smallholder farmers |
| Context (C) | Nexus between climate services and climate change adaption, which is in response to the observed and/or projected impacts of climate change in the agricultural sector |
| Scope (S) | Peer-reviewed (i.e., journals, books, and book chapters) and selected grey materials (i.e., conference papers and technical reports) |
| Time (T) | Scientific materials published from January 2015 to September 2022 |

### Search and screening strategy

This paper utilized three databases for the sourcing of the literature, namely Google Scholar, ScienceDirect, and Web of Science (WoS). Google Scholar is an open-source search engine comprised of both peer-reviewed and grey materials from an array of disciplines. Meanwhile, ScienceDirect and WoS, as bibliographic databases, are constituted of peer-reviewed materials from at least 256 disciplines.

Following the PICoST approach, multiple eligibility and exclusion criteria were identified (see Table 2). To ensure the credibility of the findings, the selected literature must be peer-reviewed or, at the very least, a conference paper and technical report, which are written in English. The material should also be published from 2015 to 2022 to ensure its timeliness and relevance. Lastly, the focus of the papers will center on climate change adaptation and climate services for the agricultural sector of Southeast Asia.

Table 2. Inclusion and exclusion criteria.

| CRITERION | ELIGIBILITY | EXCLUSION |
|---|---|---|
| **Literature type** | Journal articles, books, book chapters, conference papers, technical reports | Literature other than journal articles, books, book chapters, conference papers, technical reports |
| **Language** | English | Non-English |
| **Timeline** | Between 2015 and 2022 | <2015 |
| **Countries and territories** | Southeast Asian Countries | Non-Southeast Asian Countries |
| **Subject area** | Climate change adaptation, climate services, agriculture | Other than climate change adaptation, climate services, agriculture |

For the collation of the pertinent literature, a series of search strings were developed for the aforementioned search engines (i.e., Google Scholar, ScienceDirect, and WoS). Accordingly, the key concepts of the queries were *climate services*, *climate change adaptation*, and *agriculture*. Other keywords used were *climate field school, climate change impacts on farmers, climate advisory, small-holder farmers, Southeast Asia, Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste,* and *Vietnam*. Materials related to *climate services* without a definite reference to the *adaptation of Southeast Asian small-holder farmers* were excluded, such as *climate services for policy recommendations*.

## Data abstraction and analysis

Upon screening, the collated materials were then scrutinized and uploaded to NVIVO, a qualitative data analysis (QDA) software designed to enhance research quality by facilitating and easing the analysis process (AlYahmady & Al Abri, 2013). In particular, thematic analysis—a useful method for synthesizing key themes of large datasets (Braun & Clarke, 2006; Nowell *et al*., 2017)—was utilized to draw on the role of climate services in the adaptation of Southeast Asian small-holder farmers relative to recurring themes identified from the review. As an adaptation, the climate services in the literature were classified in accordance with the three focused areas of Vaughan & Dessai (2014), particularly (1) forecasting for informed decision-making, (2) projections of climate trends for policy-making, and strategic planning, as well as (3) monitoring and forecasting of climate hazards for disaster risk management. For the purposes of this review, the first and third theme will be condensed as *Informed Decision-Making* and *Disaster Risk Management*, respectively. Meanwhile, materials centering on the second theme were excluded in the analysis since the focus of this study are climate services as an adaptation of smallholder farmers in Southeast Asia. Subsequently, the principal and sub-themes were organized accordingly to create a typology of literature.

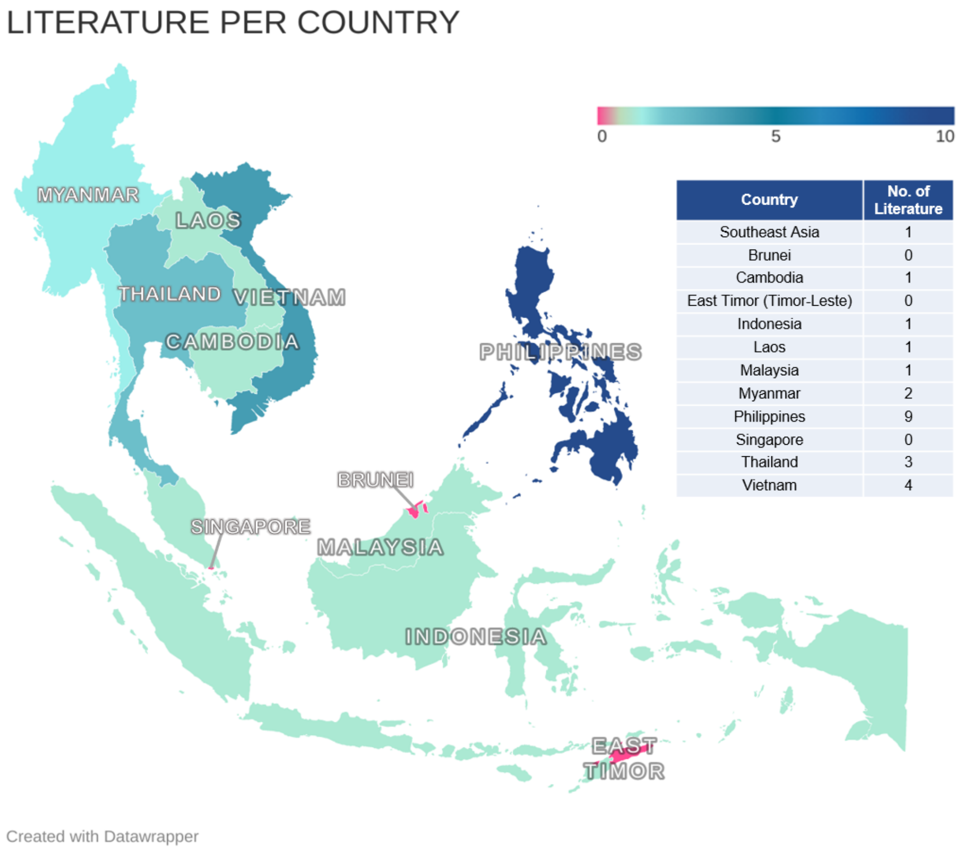
## Limitations of the Study

Given that this paper is a systematic review, it should be noted that the findings of this study are solely based on the reported information from the collated materials. Hence, the presented type of climate information may not fully capture the situation in a given country (e.g., type of available advisories, etc.).

## RESULTS AND DISCUSSION

Upon the rigorous exploration of the 3 search engines, a total of 22 materials were collated following the devised criteria with the majority of the literature concentrated in the Philippines (refer to Figure 5). Accordingly, it is interesting to note that research on the Southeast Asian smallholders' application of climate services as an adaptation strategy is scarce despite being the supplier of almost 25% of the global rice (FAO, n.d.-a). This is particularly true for the countries of Myanmar, Thailand, and the Philippines, which are not only leading rice producers (refer to Figure 1) but also one of the most affected countries by climate-related disasters from 2000 to 2019 based on the 2021 Global Climate Risk Index (Eckstein *et al.*, 2021). Likewise, the WorldRisk Report 2022 found that all of the leading producers of rice in Southeast Asia were included in the top 30 nations with the highest disaster risks out of 192 nations. In particular, the Philippines, Indonesia, Myanmar, Vietnam, and Thailand have been ranked 1$^{st}$, 3$^{rd}$, 6$^{th}$, 12$^{th}$, and 23$^{rd}$, respectively (Mucke *et al.*, 2022). However, it is worth noting that non-climatic triggers, such as earthquakes and tsunamis, have been included in the WorldRisk Report 2022. Nevertheless, this coincides with the findings of Georgeson *et al.* (2017), which revealed the inconsistency between investments and flow of climate services, and the exposure risk of a country.

Meanwhile, the lack of agricultural-related adaptation papers in Singapore and Brunei can be attributed to the fact that the former is not an agricultural country (Dedicatoria & Diomampo, 2019) while the latter has low agricultural activity (Nations Encyclopedia, n.d.). The case of Timor-Leste was primarily due to their low climate risk from the period of 2000 to 2019 (Eckstein *et al.*, 2021) despite the country's high dependency on agriculture among poverty-stricken households (World Bank, 2019). The succeeding sections will delve deeper into the thematic areas of the materials as well as the specific climate services communicated to the smallholder farmers.




| Country | No. of Literature |
|---|---|
| Southeast Asia | 1 |
| Brunei | 0 |
| Cambodia | 1 |
| East Timor (Timor-Leste) | 0 |
| Indonesia | 1 |
| Laos | 1 |
| Malaysia | 1 |
| Myanmar | 2 |
| Philippines | 9 |
| Singapore | 0 |
| Thailand | 3 |
| Vietnam | 4 |

Figure 5. Map of the literature on climate services as an adaptation strategy for smallholder farmers by country.

### Climate services in Southeast Asia

In terms of the focus areas of climate services, findings revealed that climate services are utilized by farmers to mitigate the disastrous impacts of climate change (refer to Figure 6), which conforms to the high incidences of disasters recorded in the Philippines, Myanmar, and Thailand (Eckstein *et al.*, 2021). Specifically, the strategies adopted by smallholder farmers to minimize losses and damages are adjustment of cropping calendar, modification of crop selection and/or cropping patterns (i.e., use of resilient varieties of crops), early harvesting, and weather index insurance (refer to Table 3).

Some countries have also established early warning systems, namely Laos (Kim *et al.*, 2022), Malaysia (Tang, 2019), Myanmar (Horton et al., 2017), Thailand (Sinnarong *et al.*, 2022), Philippines (APAARI, 2018; Cinco *et al.*, 2020; Diona II et al., 2020; Gata *et al.*, 2020; Ruzol *et al.*, 2020), and Vietnam (Sen *et al.*, 2021). These are typically managed by the government agency mandated to collect and disseminate meteorological information. Other climate services offered by such institutions are seasonal climate forecasts, climate change projections, climate monitoring, analysis and diagnostics, as well as tailored products (Meteorological Service Singapore *et al.*, 2017).

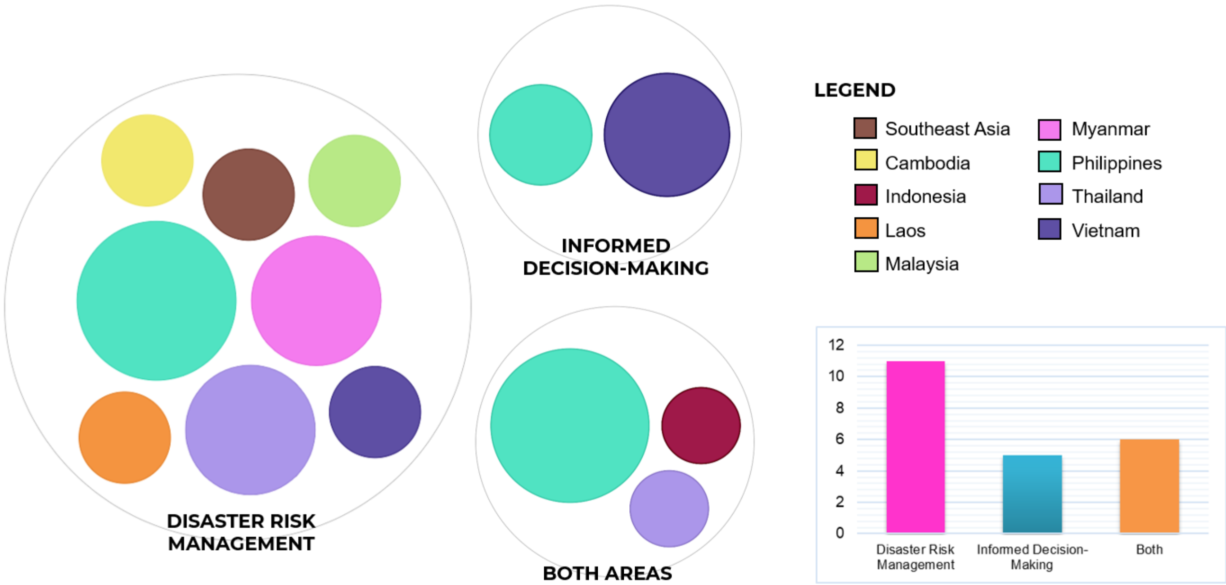



Figure 6. Key focus areas of the climate services utilized by small-holder farmers in Southeast Asia per country following the classification of Vaughan & Dessai (2014). Node sizes are proportional to the number of literature in which it was cited. Meanwhile, the bar graph on the lower right reflects the total number of literature per focus area.

Table 3. Adaptation strategies of smallholder farmers per country.

| Adaptation strategy | Country and author(s) |
|---|---|
| Adjustment of cropping calendar | • Indonesia - *Banowati et al. (2019)*<br>• Myanmar - *Horton et al. (2017)*<br>• Philippines - *Chandra et al. (2017); APAARI (2018); Hayman et al. (2020); Launio et al. (2020)*<br>• Thailand - *Arunrat et al. (2017)* |
| Modification of crop selection and cropping patterns | • Indonesia - *Banowati et al. (2019)*<br>• Philippines - *Chandra et al. (2017); Launio et al. (2020)*<br>• Thailand - *Arunrat et al. (2017)* |
| Early harvesting | • Philippines - *Dedicatoria & Diomampo (2019); Diona II et al. (2020); Cinco et al. (2020); Ruzol et al. (2020)* |
| Weather index insurance | • Thailand - *Sinnarong et al. (2022)*<br>• Vietnam - *Shaffril et al. (2018)* |

## Types of climate information

Delving further, the particular climate-related information used by Southeast Asian small-holder farmers to avoid hazards and guide their farming activities are rainfall, wind (i.e., including speed and intensity), temperature, humidity, soil moisture, leaf wetness, water level, and indigenous knowledge with the former three being the most cited (refer to Figure 7). Similarly, precipitation, temperature, and wind were found to be the recurring climatic variable at the country level (see Figure 8). Apart from being a tropical region, the prevalence of such climate information was unsurprising given the association of drought to rainfall and temperature (Fung *et al.*, 2020) as well as tropical cyclones to wind and rainfall (Chen *et al.*, 2020). Moreover, rainfed cultivation areas—which constitute roughly about 99 million ha in Southeast Asia (Devendra, 2011)—are highly dependent not only on precipitation intensity and duration (Hayashi *et al.*, 2018) but also on temperature variabilities (Singh *et al.*, 2017).

For indigenous knowledge, the common traditional indicators used by smallholder farmers are the presence of birds and insects (Arunrat *et al.*, 2017; Launio *et al.*, 2020). The Thailand farmers, in particular, also refer to the flowering season of a bermuda grass (*Cynodon dactylon*) and tamarind (*Tamarindus indica*) in forecasting the precipitation volume with the latter entailing a scarcity in amount and abundance for the former (Arunrat *et al.*, 2017). While the potential of indigenous-based forecasts is undeniable (Shaffril *et al.*, 2018; Launio *et al.*, 2020; Petzold *et al.*, 2020), the variability of the recent climate makes it difficult for the farmers to predict extreme weather events, such as flooding and droughts *(Arunrat et al.*, 2017). Recent studies have also shown that climate change will alter the flowering phenology of tropical flora (Butt *et al.*, 2015) as well as the habitat range of insects (IPCC, 2018) and tropical birds (Şekercioğlu *et al.*, 2012), ultimately augmenting the unpredictability of extreme weather events.

Country-wise, the exhaustiveness of the climatic variables in the Philippine literature was principally due to the prominence of a detailed referencing to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in such materials. On the contrary, the paper on the adaptation of Cambodian farmers did not specify the type of climate-related information, which helped the aforementioned farmers minimize the risks from climate change. Meanwhile, the monitoring of the water levels in Malaysia can be considered an adaptive mechanism in response to the substantial losses of the agricultural sector (i.e., RM 90.6 million for the period of late 2021 to early 2022) attributable to flooding (Department of Statistics Malaysia, 2022).

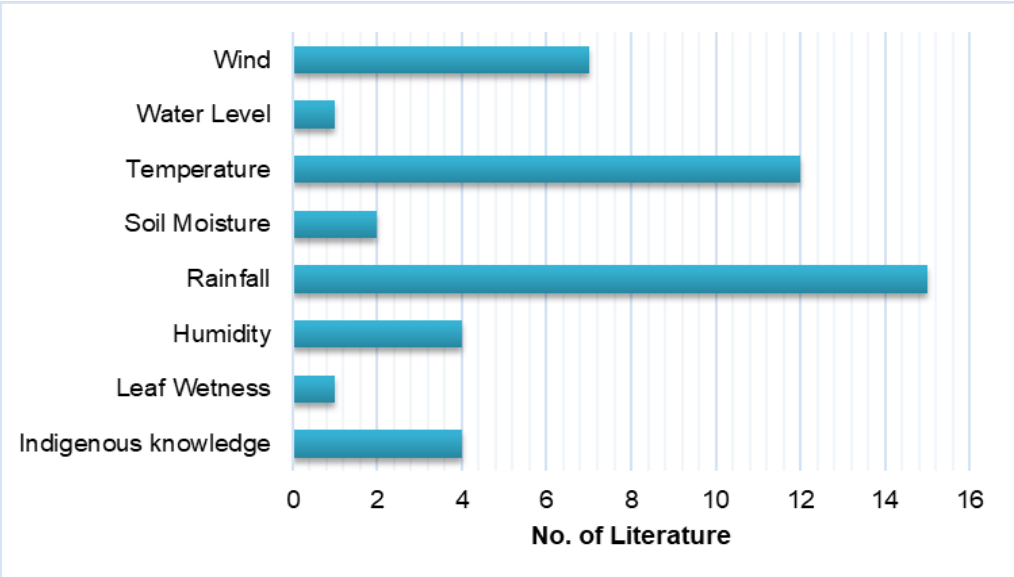



Figure 7. Different types of climate-related information based on the literature review.

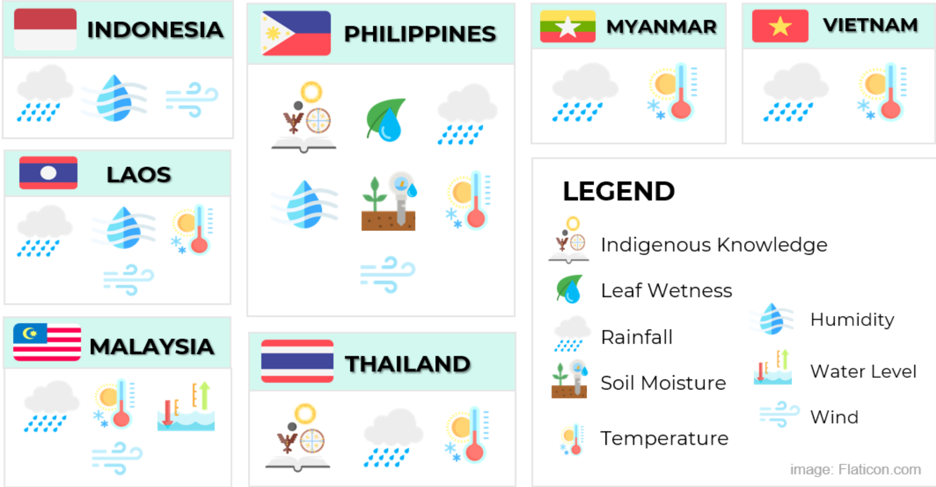



Figure 8. Type of climate-related information used by small-holder farmers to adapt to the changing climate identified from the review.

Through the above-listed meteorological information, government agencies of selected countries have developed advisories to further help the farmers adapt to the changing climate (see Figure 9), which are posted on their official websites (Dedicatoria & Diomampo, 2019). Generally, the smallholder farmers acquire these advisories from local weather stations, newspapers, local beliefs, dialogues with other farmers, television, radio, and SMS (i.e., mobile) with the latter three being the most prevalent (Gata *et al.*, 2020; Sen *et al.*, 2021). Apart from the above-listed medium of information dissemination, the Governments of Indonesia, Malaysia, Myanmar, Philippines, and Thailand have also leveraged the prevalence and pervasiveness of social media (i.e., Facebook, Twitter, Instagram) to reach a wider audience (Dedicatoria & Diomampo, 2019). Nonetheless, a recurring concern regarding these forecasts is their inability to fully capture local conditions (Gata *et al.*, 2020; Sen *et al.*, 2021).

A notable example of this scenario is the weather advisory for Super Typhoon Rai, wherein the intensity level leaped from signal no. three to five (Suson, 2021). The imprecision of tropical cyclone forecasts is principally ascribed to a unique phenomenon called rapid intensification (Fischer *et al.*, 2019; Chen *et al.*, 2020). Rapid intensification, as defined by Song *et al.* (2020), is the dramatic rise in the intensity of tropical cyclones in a relatively short span of time. But in general, another potential reason for the inaccuracy of weather/climate advisories is the limited attention to the quality assurance and standards dimension of climate services, which is responsible for the suitability, credibility, and saliency of such climate services (Hewitt & Stone, 2021).

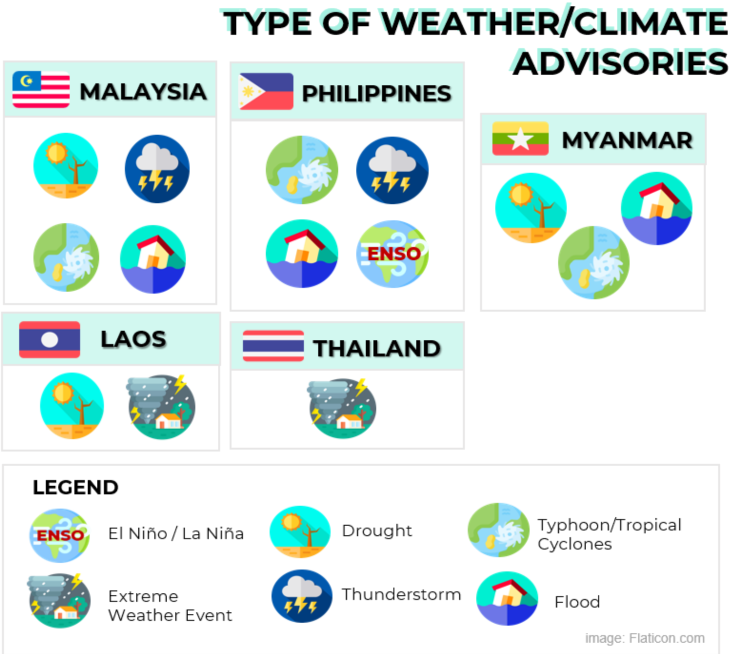



Figure 9. Type of weather/climate advisories identified from the review.

## CONCLUSION AND RECOMMENDATIONS

Despite the observed and projected impacts of climate change in the agricultural sector, the systematic review of climate services available to Southeast Asian farmers revealed the poverty of literature from 2015 to 2022. The unevenness in the number of publications is associated with the relevance of agriculture and the degree of climate-related risks to the countries. Accordingly, these climate services are often utilized to guide the activities of the farmers toward disaster risk management and reduction (i.e., adjustment of cropping patterns, early harvesting, etc.). In terms of climate information types, there is a rich list of climatic variables available to the farmers. However, it is imperative to localize such information, including weather/climate advisories, for these climate services to be beneficial to small-holder farmers (Ruzol *et al.*, 2020). As such, this paper recommends the incorporation of indigenous knowledge on technological advancements in the field of climate services for a more accurate delivery of information.

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## AUTHORS' CONTRIBUTIONS

Juan M. Pulhin led the overall conceptualization and design of analytical framework and methodology of the research, and participated in the writing and finalization of the paper; Mary Beatrice S. Evaristo contributed in the conceptualization of the research, and led the data gathering and writing of the paper; and Millicent Joyce Q. Pangilinan contributed to the conceptualization, data gathering, writing, and editing of the paper.

## CONFLICT OF INTEREST

All the three authors, Juan M. Pulhin, Mary Beatrice S. Evaristo, and Millicent Joyce Q. Pangilinan declare that they have no conflict of interests.