Determination of the Climate Change Adaptability of Paddy-growing Farmers in Ampara District, Sri Lanka: A Case Study

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***Abstract*—Climate change poses a substantial threat to global agricultural systems, impacting the livelihoods of millions of farmers. This study endeavors to evaluate the adaptability of paddy farmers in the Ampara district of Sri Lanka—a region susceptible to changing climate patterns—in response to the challenges posed by climate change. A survey, utilizing a questionnaire, was administered to 100 voluntary participants. 73% of respondents derived their primary income from paddy cultivation, and all respondents exhibited awareness of climate change. Interestingly, 17% of participants relied solely on rainwater, while 69% met their water needs through a combination of rainwater and reservoirs. A significant majority, 98%, observed fluctuations in seasonal rainfall compared to previous years. The respondents employed diverse adaptation strategies, including modifying planting schedules, altering crop varieties, and adjusting irrigation practices. Among the surveyed group, 21% resort to rainwater collection, and 8% employ sediment removal techniques to improve the storage capacity of their irrigation reservoirs. Additionally, only 28% of respondents have transitioned to short-shelf-life rice varieties. Notably, 34% have adjusted their rice planting schedules to ensure sufficient water availability. 59% of the respondents have substituted indigenous paddy varieties such as Samba, AT 362, and BT 300 that can withstand climate change such as heavy floods and prolonged drought. Policymakers and stakeholders have the opportunity to devise focused initiatives aimed at enhancing the resilience of farmers confronting the challenges posed by climate change.**

Keywords—Rice cultivation, climate change adaptation, awareness, challenges

I. Introduction

Developing countries which are located in the tropical region are more susceptible to climate change-induced rising temperatures, and frequent floods [1]. The agricultural sector is considered one of the most vulnerable sectors to climate change [1, 2]. The change in the climatic parameters can impact significantly on irrigated agriculture [3]. The developing world is more vulnerable than the developed world because of its greater reliance on the agriculture sector for subsistence, lack of technological advancement, and absence of policies to adapt to climate change on agricultural production [1]. Climate change reduces agricultural productivity and increases the vulnerability of small and medium-sized respondents, whose primary sources of income are agriculture and related industries [1].

In Sri Lanka, 30% of paddy farming is dependent on rainfall, and 70% is dependent on irrigation [2]. Paddy fields that rely on large irrigation projects are less susceptible to short-term droughts but more susceptible to severe ones [2].

Low rainfall during the Maha season caused significant crop loss both during the season and the Yala season that followed [2]. The effects of climate change will include pollen desiccation, decreased production, an increase in pest and disease outbreaks, soil degradation, and decreased yield [2]. Rising temperatures can increase the rate of evapotranspiration and lower the water level in tanks and rivers [2, 3]. High levels of transpiration and evaporation can reduce soil moisture, stream flow, and groundwater recharge [3]. This can reduce the amount of water available for farming and increase the requirement for irrigation [3]. Soil salinization is a potential issue that arises from higher evaporation and decreased rainfall, which leads to a greater build-up of salt in the soil [3].

Furthermore, [4] found that paddy grown in rainfed lowlands is more vulnerable to weed competition than that in irrigated lowlands, suggesting that the availability of water has a significant role in determining the degree of weed interference [5]. Besides, the climatic zone will also affect the competitive pressure that weeds place on crops in the moisture-stressed dry zone; weed pressure is stronger than in the wet zone [5]. And, weed competition in Sri Lanka reduces paddy yield by around 20 - 40% or even 80 - 90% [5]. Thus, paddy cultivation in the dry zone is more vulnerable to climate change due to prolonged droughts and deficiency of rainfall [3]. So, it is crucial to comprehend and address the adaptive capability of rice respondents in the dry zone to guarantee the long-term sustainability and food security of Sri Lankan rice production. Researchers and policymakers can create tailored interventions to support rice respondents in the dry zone in their efforts to adapt by having a thorough grasp of the unique obstacles they encounter. The scope of this study is limited to Ampara district which is one of the major rice production regions in Sri Lanka. The Ampara district is severely affected by prolonged droughts and heavy rainfall due to climate variability. Thus, the determination of the adaptability of respondents in the Ampara district is crucial to identify the constraints, gaps, and opportunities to continue their production without compromising any loss.

II. Materials and Methods

A. *Study Area*

Ampara district in the Eastern Province was selected as the study area for this study. Lahugala (Waralanda, Dawalgoda, Perani Lahugala), Panama (Panama north, Panama South, Panama Central, Panama Western), Uhana (Gonagala, Senagama, Verenkatagoda Mayadunna, Kothmale (K.C. Colony), Bandaraduwa, Gonagolla) Paragahakele), Dehiattakandiya (Lihiniyagala, Damunnuwara) Divisional Secretariat divisions were selected for this study.

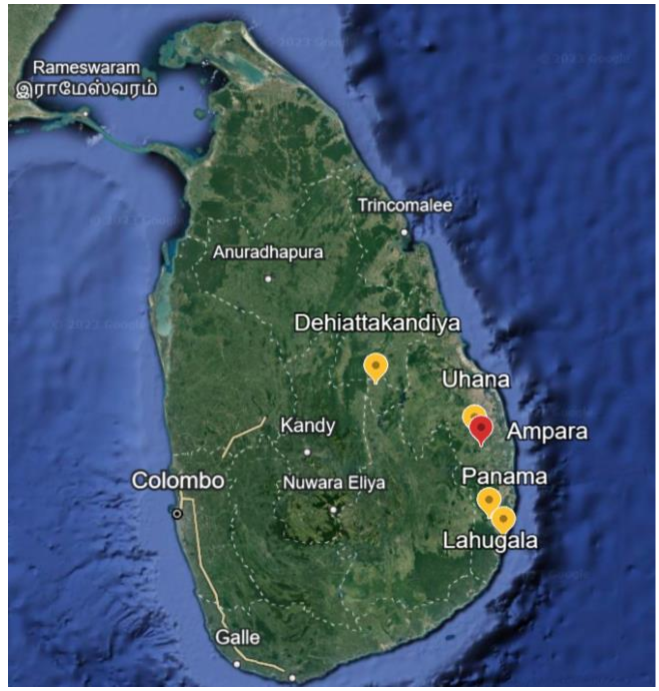

Fig. 1: Areal view of study area (google earth)

B. *Questionnaire Survey*

A questionnaire-based study was conducted to collect data on rice production and other climate impacts. A population of 100 respondents was selected based on the random sampling method. The questionnaire survey was conducted physically in September 2023. The questionnaire consisted of 9 main sections with 67 questions, closed-ended questions, and open-ended questions. The nine sections included: Section 1- Demographic Information (Q1.1 - Q1.12), Section 2 - Climate Change Awareness (Q2.1 - Q2.2), Section 3 - Water supply (Q3.1 - Q3.12), Section 4 - Impact of rainfalls (Q4.1 - Q4.10), Section 5 - Impact of dry weather on rice crops (Q5.1 - Q5.8), Section 6- Pest and diseases (Q6.1-Q6.8), Section 7 - Crop loss and compensation (Q7.1 - Q7.4), Section 8 - Adaptation Practices (Q8.1 - Q8.9), and Section 9 - Access to Resources (Q9.1 - Q9.4).

Ethical consent was obtained from individuals before the research due to their participation in this study. Also, the individuals were informed at the beginning of the survey that their demographic details and responses to the questions would be collected only for the study. All the respondents participated in the survey as volunteers and before the survey, they were informed about the purpose of the study and its main results and participated in the survey based on their consent. The collected information was analyzed using Excel software and the respondents were tabulated as a percentage of the total number of respondents and analyzed as the final result.

III. Results and Discussion

A. Demographic Characteristics of the Respondents

Responses to the demographic characteristics of the respondents are tabulated as percentages from the total number of responses as given in Table 1. 73% of them are mainly engaged in paddy cultivation as their livelihood, 6% are engaged in chena cultivation and 3% are engaged in retail trade. During last *Yala* season, only 7% have successfully attained their anticipated crop yields. 91% of the respondents failed to attain the harvest as they expected due to inadequate fertilizer distribution, the quality of fertilizers, and irregular rainfall patterns. However, 2% of the respondents managed to achieve average yields. Respondents grow other crops such as peas, green beans, peas, melons, and kurakkan to enrich the soil, especially with nitrogen and phosphorus. Only 2% of respondents grow as intercrops in all intermediate seasons. 48% of the respondents cultivate intermediate crops in some intermediate seasons, and 50% of respondents never grow intercrops other than paddy.

B. Climate Change Awareness

All the farmers (100% of the respondents) were aware of climate change and its potential impacts on agriculture. 98% of respondents have observed changes in climate patterns in their regions over the past decade, while 2% have not observed any change with respect to their climate.

C. Water Supply

As shown in Fig. 2, the majority (69%) of respondents fulfill their water requirements through both rainwater and reservoirs. The channels from the main reservoirs provide water for the remaining 2% of the respondents. The respondents who depend on rainwater entirely lack proper methods such as irrigation tanks to store rainwater during the rainy season. So, these respondents only cultivate during the *Maha* season of the year. 23% of respondents get irrigation water from the main reservoir (Senanayake reservoir) (Figure 3), 38% of respondents from canals, and 39% of respondents from village tanks (Ulhitiyawa Lake, Maha Lake, Meeyangoda Lake, Namal Oya). And some other respondents' cross canals to collect water.

40% of respondents reported that flooding and bank breaches had impacted the irrigation reservoirs in their regions. To mitigate the flood-related damage to these reservoirs, respondents employed strategies such as constructing embankments and deploying sandbags near the areas with high water levels. On the other hand, for 60% of respondents, the irrigation reservoirs in their areas remained unaffected by floods.

Table 1: Demographic Characteristics of the Selected Population (As A Percentage of the Total Population of 100)

Demographic features		Percentage
Age	30-39 years	10%
	40-49 years	18%
	50-59 years	40%
	60-69 years	32%
	70-79 years	7%
	80-89 years	1%
Gender	Male	86%
	Female	14%
Experience of paddy cultivation	less than 10 years	6%
	10-20 years	8%
	20-30 years	18%
	30-40 years	30%
	40-50 years	26%
	50-60 years	12%
Extent of paddy cultivation	less than five acres	75%
	5-10 acres	15%
	10-15 acres	7%
	15-20 acres	3%

conducting discussions and ensuring the equitable distribution of water between upper and lower paddies can serve as a viable solution to mitigate such conflicts.

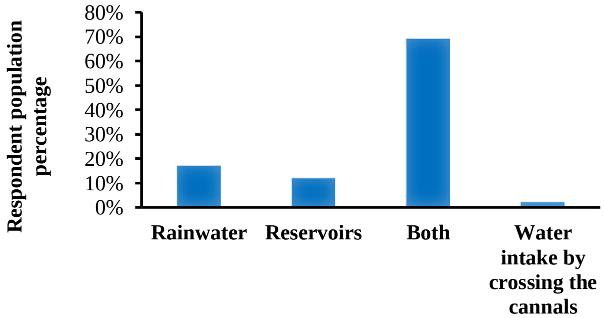

Fig. 2. Main source of water for paddy cultivation of the responded population

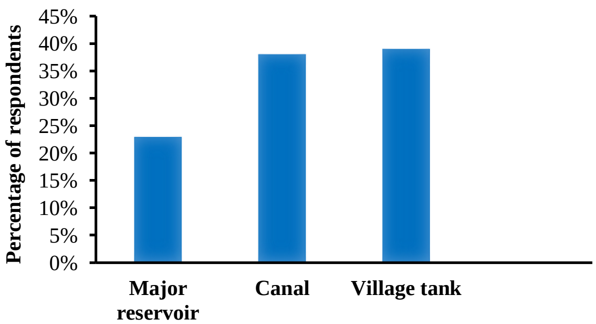

Fig. 3. Methods of irrigation water supply of the responded population

According to all the farmers, government organizations, specifically the Irrigation Department, have been diligently working on restoring the impaired reservoirs to their optimal operational state. 15% of these respondents have taken the initiative to refurbish their abandoned irrigation tanks, which include the Maha Lake, Yalpotha Lake, and Kithulana Lake. Additionally, 7% of respondents in their respective villages have implemented substantial mega irrigation projects, such as Heda oya, Wegama Lake, and Adal oya, to ensure a consistent water supply for paddy cultivation. However, the remaining 93% of villages do not have access to mega irrigation projects. In the surveyed agricultural regions, several respondents have proactively adopted water conservation practices for their paddy cultivation activities, particularly during the dry season. Notably, 21% of these respondents engage in rainwater collection, while 8% implement sediment removal techniques to enhance the storage capacity of their irrigation reservoirs. Regrettably, the majority of respondents, constituting 71%, have yet to employ any water conservation methods. Moreover, 43% of the respondents faced conflicts arising from water scarcity during extended drought periods, while 57% of them managed to avoid such conflicts. Encouragingly, for 81.8% of the respondents, engaging in discussions proved to be an effective means of resolving these water-related challenges. Furthermore, 18.20% of the respondents believe that

D. Impacts of Rainfall

The monsoon rains play a pivotal role for rice farmers residing in the dry zone, as their livelihoods are intricately linked to irrigation reservoirs primarily replenished by rainfall. Additionally, some farmers directly rely on rain for their water supply. Furthermore, all farmers conduct essential tillage operations in their fields, predominantly contingent upon the presence of rainfall. Notably, 98% of these respondents have noticed variations in seasonal rainfall when compared to previous years, underscoring the changing climate patterns. In contrast, a mere 2% of the respondents have not observed such fluctuations. The majority of respondents, accounting for 66%, have noticed alterations in rainfall patterns during both the Maha and Yala seasons. Furthermore, 29% of the respondents have specifically observed shifts in the Maha season, while a mere 3% have reported changes in the Yala season. However, a small fraction of 2% of the respondents have not discerned any variations in monsoonal rainfall.

As reported by the majority of respondents, specifically 97%, the monsoon rains were delayed, arriving later than the expected schedule. In contrast, only 3% of respondents received the monsoonal rains at their usual time. In terms of crop losses, around 53% of respondents experienced losses ranging from 0-1000 kg. Within this group, 13.2% faced complete crop failure during certain seasons. Additionally, nearly 14% of respondents incurred losses between 2000 kg and 5000 kg, while 19% experienced losses ranging from 1000 kg to 2000 kg. A smaller fraction, 1%, had more substantial losses, falling within the range of 5000 kg to 10,000 kg. Furthermore, 6% of the remaining respondents reported both partial and total damage to their crops. Surprisingly, 7% of respondents held the belief that rainfall does not pose a threat to their crops.

The influence of rainfall on paddy cultivation can fluctuate depending on the specific stages of the paddy's life cycle. Approximately 55% of the respondents encountered substantial challenges from rainfall during the harvest period, while roughly 16% faced significant impacts during the ripening phase. A smaller percentage, approximately 2%, reported adverse effects during the vegetation stage. In addition, 17% of the respondents mentioned that their crops were damaged specifically during the ripening stage, and 1% indicated damage occurring solely during the harvesting period. A distinct group of 7% of the respondents suffered from damages during all three phases of the vegetation period, ripening period, and harvesting period.

Reduction in rainfall and increased unpredictability will disrupt the cropping calendar in addition to impacting crop output [6]. In Sri Lanka, later monsoon arrivals can result in shorter growing seasons [6]. Rainfall can have various detrimental effects on rice cultivation, including damage caused by mites, crop loss during the ripening phase, reduced yields, stunted plant growth, rotting of plants in waterlogged paddy fields, insect infestations, formation of unproductive pods, yield reduction due to pollen washout, and inundation of crops due to flooding. Furthermore, heavy rains can result in damage to paddy fields through tree uprooting, dam breaches, crop destruction, soil erosion, and sediment deposition in fields. During the harvesting stage, excessive rainfall can impede proper harvesting and hinder the drying process for the harvested paddy.

E. Impact of Dry Weather on Paddy Cultivation

The duration of the dry season in the Ampara district varies depending on the area. In some areas, the dry season extends for a period of eight months, while in others, a severe drought can persist for two months. These extended dry periods, characterized by insufficient rainfall, have significant consequences for agriculture. Elevated nighttime mean temperatures have a pronounced effect on rice production, as demonstrated by various studies [6]. Research conducted at the International Rice Research Institute farm revealed a 10% decline in paddy yield for every 1°C increase in the minimum temperature during the growing season in the dry season [6].

Elevated temperatures pose a threat to lower-altitude regions worldwide, especially those already experiencing warm conditions [7]. In regions where climate change leads to temperatures surpassing optimal levels, there is an escalation in the release of CO_2, accompanied by a reduction in photosynthesis activities. This ultimately impacts plant physiology and yield [7]. Similarly, temperatures higher than the optimal range or warmer conditions foster increased insect pest growth, elevating the risk of reduced plant production [7]. Climate change further alters the patterns of rainfall, affecting the extent and distribution of evapotranspiration [7]. This disruption influences soil water content, drainage, runoff, and water uptake by plants [7]. Both flooding and drought, stemming from these climate shifts, adversely impact crucial plant growth stages such as flowering, pollination, and grain filling [7].

Elevated temperatures have a detrimental impact on cellular and developmental processes, resulting in decreased fertility of spikelets and reduced grain weight [7]. This adverse influence extends to the quality of the grains, manifesting as a higher percentage of chalkiness and lower amylose content during the grain filling and ripening phase in rice [7]. The persistent rise in temperature further shortens the plant growth cycle, adversely affecting rice yield [7]. During the dry season, respondents in the Ampara district collect water from sources such as Senanayake and regional tanks, as well as irrigation channels, which they then distribute using pipes. However, in areas lacking water resources, such as Panama and Lahugala, cultivation during the Yala season becomes unfeasible. Consequently, the agricultural productivity of the Ampara district during the dry season is hampered by the unavailability of a continuous water supply. This study has confirmed that both the reproductive and vegetative stages of rice are particularly susceptible to drought in this region during paddy cultivation. A significant majority of respondents, approximately 93%, have adapted to the practice of applying liquid fertilizers during the morning and evening. This method helps to mitigate fertilizer loss caused by intensified solar radiation. In contrast, 7% of respondents do not employ liquid fertilizers. Additionally, around 9% of respondents have opted for an organic fertilizer known as "Jivashakti fertilizer," which demonstrates resilience against evaporation-related losses

F. Pests and Diseases

In paddy cultivation during adverse weather conditions, various pests, including caterpillars (such as green hornworms), thrips, aphids, mites, worms (like earworms and cutworms), rice flies, grasshoppers, bugs, and butterflies, are commonly encountered. Fungal diseases tend to be more prevalent during dry seasons, as wind and temperature fluctuations influence their spread. Effective management of insects during warm weather can significantly reduce damage. To address these issues, a range of control measures, such as the use of insecticides, seeking guidance from agricultural experts, periodic cultivation, and the drainage of excess water from paddies, are typically employed in standard agricultural practices within these regions. However, in the Ampara district of the dry zone, elephants pose the primary threat to paddy respondents during unfavorable weather conditions. These majestic creatures inflict severe damage to paddy crops through both consumption and trampling. The individuals engaged in paddy cultivation often face various health issues, including rat fever, skin ailments, respiratory issues, kidney disease, gout, and damage caused by caterpillars. The increased incidence of rat fever is particularly associated with high levels of rainfall.

G. Crop Loss and Compensation

Out of the surveyed respondents, 31% have been recipients of government compensation to offset harvest losses, while the remaining 69% have not received such compensation. Regarding financial recovery, 33% of respondents rely on credit to cope with their losses, while the majority, constituting 67% of the respondents, do not depend on credit. In terms of livelihood adjustments due to climate change-induced crop losses, 8% of respondents have changed their primary source of income, whereas the overwhelming majority, accounting for 92% of the respondents, have retained their original source of income.

H. Adaptation Practices

[8] classified agricultural adaptation possibilities into four key categories: (1) government programs and insurance; (2) technical improvements; (3) farm production techniques; and (4) farm financial management. Government agencies make most of the decisions in categories 1 and 2, whereas producers make the majority of the decisions in categories 3

and 4. In this study, categories 3 and 4 were mainly focused. Only 28% of respondents shifted into short-shelf-life rice varieties such as H10, and Basmathi (75 days)], while the remaining 72% of the respondents have not adopted short-shelf-life rice. 34% of the respondents have changed their rice planting times to get enough water (Figure 4), and 66% of the respondents have not changed their rice planting times. 79% of the respondents were aware that local rice varieties such as H4, H5, H8, and BG11 can withstand climate change such as heavy floods and long droughts, and according to 21% of the respondents, the local rice varieties cannot withstand climate change. 59% of the respondents have substituted indigenous paddy varieties such as Samba, AT 362, and BT 300 that can withstand climate change such as heavy floods and prolonged drought, while 59% of the respondents have not substituted indigenous paddy varieties.1% of respondents have shifted to areas that are less vulnerable to the effects of climate change, while 99% of respondents have not 20% of the respondents have changed to crops that can withstand extreme climate conditions and 80% of the respondents have not changed to other crops. 15% of the respondents have changed their paddy cultivation to crop types such as peanuts, mung beans, cowpeas, and bananas that can withstand extreme climatic conditions, while 85% of the respondents have not changed their paddy cultivation to other crop types. Reduction in rainfall and increased unpredictability will disrupt the cropping calendar in addition to impacting crop output. In Sri Lanka, later monsoon arrivals can result in shorter growing seasons [6]. As shown in Figure 4, changing planting dates, using drought-resistant rice varieties, altering irrigation methods, crop rotation or diversification, and soil conservation practices have been identified as key adaption measures

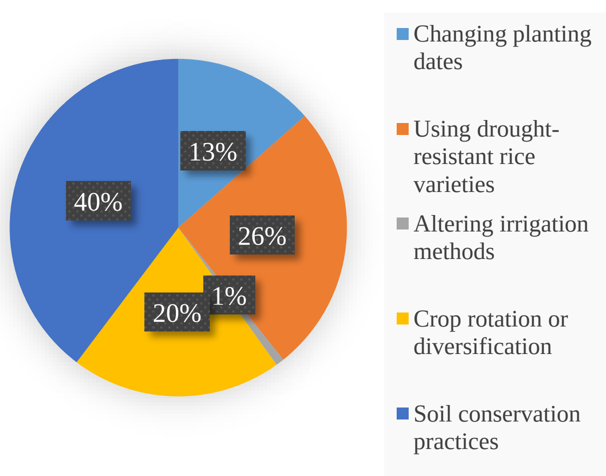

Fig. 4. Adaptation practices farmers have implemented or considered to address climate-related challenges

I. Access to Resources

A respondent's ability to successfully adapt and respond to the challenges of climate change is intricately tied to their knowledge, skills, past experiences, and various socio-economic factors [9]. A significant 90% of respondents have access to climate information and forecasts specific to their region. In contrast, 10% of respondents lack access to such vital climate information and forecasts, primarily due to lower technical literacy and financial constraints. Nonetheless, it's important to note that general weather forecasting doesn't always provide location-specific meteorological data, which can impede respondent’s adaptation efforts in the face of ongoing extreme weather conditions. 7% of respondents have financial or resource constraints that hinder their ability to adopt climate-resilient practices, and 93% have no such financial or resource constraints. 26% of respondents have government programs or initiatives supporting climate-resilient paddy cultivation in their regions, and 74% of respondents do not have these government programs or initiatives. Regarding government programs or initiatives to support climate-resilient rice cultivation in this area, some selected individuals participate in the Yala and Maha seasons meetings, programs of respondents’ associations, and programs conducted by the Department of Agriculture. 62% of respondents have participated in government-led training programs related to climate change adaptation in agriculture, while 38% of respondents have not.

I. Way Forward

To enhance respondent’s resilience in the face of extreme climatic conditions, the adoption of climate-smart agricultural practices is crucial. Implementing temporary check dams constructed from sandbags or polybags can effectively store rainwater in reservoirs, bolstering water availability and groundwater replenishment. Furthermore, the introduction of direct-seeded rice cultivation is a viable option, as it helps to conserve water. Unlike transplanting paddy, which leads to water loss through runoff, percolation, and evaporation, direct seeding proves to be more efficient. Additionally, the utilization of micro-irrigation techniques, including surface drip irrigation and subsurface drip irrigation, offers the flexibility to apply water according to the specific needs of the crops. This approach minimizes water loss through percolation and surface runoff. Moreover, the implementation of the Alternative Wetting and Drying (AWD) method stands out as a promising strategy, as it significantly enhances water productivity compared to traditional flooded fields or submerged regimes. In addition, government funding should be allocated for the establishment of rainwater harvesting systems in areas lacking the necessary infrastructure. Initiatives like the installation of rainwater harvesting tanks, the construction of irrigation reservoirs, and the development of canals to redirect water from existing irrigation sources can empower respondents in this region to sustain agricultural activities even during prolonged dry spells.

It is imperative to arrange awareness programs at the grassroots level to help respondents recognize the significance of adapting to climate change. Additionally, effective weather forecasting plays a pivotal role in assisting paddy respondents in their adaptation efforts to mitigate the impacts of extreme climatic conditions. To improve respondent's access to weather and climate information and enable them to make informed decisions, it is essential to boost their digital literacy. Facilitating the sharing of weather information among fellow respondents can be especially beneficial for those facing financial constraints, allowing them to access timely weather updates. Furthermore, the government should allocate funding for the installation of additional meteorological stations in regions more prone to drought. This investment will ensure the availability of location-specific meteorological data, ultimately aiding respondents in managing extreme weather conditions effectively.

IV. CONCLUSION

This study underscores the pressing necessity to address the adaptability of paddy respondents in the dry zone to climate change. The profound impacts of shifting climatic conditions, coupled with financial limitations and a lack of awareness, pose substantial hurdles. Promoting climate-smart agricultural practices is of paramount importance in bolstering resilience within this vulnerable region. It is imperative to concentrate on furnishing financial assistance, enhancing awareness, and equipping respondents with the requisite knowledge and tools to secure a sustainable and flexible future for paddy farming in the dry zone.

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