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# Perceptions of Climate Change and Adaptation of Climate-Smart Technology by the Paddy Farmers: A Case Study of Kandy District in Sri Lanka

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***Abstract*—**Kandy district in Sri Lanka, has small scale and rain-fed paddy farming, and highly vulnerable to climate change. In this study, the status of climate change was assessed using meteorological data and compared with the perceptions of paddy farming community. Factors affecting the adaptation to the climate smart farming were also assessed.

Meteorological data for 33 years were collected and the changes over time compared with the perceptions of farmers. The temperature, rainfall and number of rainy days have increased in both locations. The onset of rains also has shifted. The perceptions of the majority of the farmers were in line with the actual changes. The knowledge and attitudes about the causes of climate change and adaptation were medium and related to level of adoption. Formulating effective communication strategies, and a collaborative approach involving state, private sector, civil society to make Sri Lankan agriculture 'climate-smart' is urgently needed.

***Keywords***—Adaptation of climate-smart technology, climate change, perception, rain-fed paddy.

## I. Introduction

### *A.Background*

GLOBAL climate change is the most serious threat faced the contemporary society. Anthropogenic climate change presents very significant risks to ecosystems and human societies [1]. Water scarcity resulting from climate change has been forecast to significantly reduce crop productivity, lead to unsustainable irrigation practices such as over-exploitation of aquifers, and to water quality issues resulting from seawater intrusion [2]. In Asia, less predictable rainfall patterns including changes in the timing and volumes of monsoonal rainfall and changes in river flows constitute the ominous threats. Many of these unprecedented changes of weather patterns impose a substantial challenge to agriculture in many tropical countries and expected to be amplified with time at an increasing rate [3].

Agriculture systems world over contribute substantially to the greenhouse gas emissions [4]. As a small island and also as a developing country, Sri Lanka's contribution for the global green house gas emissions is minimal, yet the vulnerability to the consequences of the climate change is high in Sri Lanka. In developing countries there are many more areas other than the environment that are vulnerable to the direct and indirect effects of climate change [5]. According South Asia Watch on Trade, Economics and Environment [6], rice cultivated in most South Asian countries show a gradual stagnation in production levels mainly caused by the changes in temperature regimes. In Sri Lanka, the paddy farming is one of the most vulnerable sectors from the effects of climate change, in terms of both quality and quantity [7]. According to estimates by the Climate Change Secretariat of Sri Lanka [8], vulnerability of irrigation to increases in drought is widespread in the island. The rain-fed paddy fields in most parts of the island, especially in the drier districts are the most seriously threatened.

There are two approaches to address the climate change issues in agriculture. In the long run, mitigation is necessary by reducing the level of global green house gases. On the other hand, it is urgent for the livelihoods of farming communities to adapt to the escalating climate change. The Global Science Conference on Climate-Smart Agriculture [9] resolved to promote 'climate-smart' agriculture as a response to the challenges of food security, poverty eradication, and climate change adaptation and impact mitigation in the context of a growing world population. Climate-smart agriculture involves the production of food crops, livestock and bio-fuels using low-carbon technologies based on reduced energy and water usage [10], as well as adopting drought or flood resistant varieties and changing management practices. A good deal of effective climate-smart practices could be found in many developing country agricultural systems. Many of these techniques used in climate-smart agriculture are based on proven techniques, such as mulching, intercropping, integrated pest and disease management, conservation agriculture and weather forecasting [11].

The timely behavior changes of the paddy farmers are essential for the successful adaptation to the climate change in the paddy sector. It is essential to develop effective mechanisms to share the research findings and resultant technologies on climate change adaptation with the paddy farmers, for their successful implementation. Paddy farmers operating under rain fed conditions are worse off due to changing climate, and hence, their knowledge, perceptions and attitudes are very important psychological factors that are influencing the adaptation of climate-smart farming systems.

This paper first attempts to explore the various efforts made by scientists and communicators to bring out the core issues

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related to climate change in Sri Lanka and tropical Asia, and to highlight how the perceptions of farmers on the causes and effects of climate change are comparable with the corresponding real scientific facts. We start by discussing the research reported in several countries and international forums explaining the realities of climate change and their effects on crop farming. This is followed by a presentation of empirical studies undertaken related to the climate change and its perceptions by the Sri Lankan farming communities. A special case study is then presented on the major outcomes of the empirical investigations undertaken on the climate change data and their consistencies with the perceptions of two selected communities representing the mid country wet and semi-dry zone of Sri Lanka. The demographic characteristics, knowledge, attitudes and level of adaptations of climate-smart technologies by these farmers are also discussed in an attempt to identify the major factors affecting the adaptation of relevant climate-smart technologies. Finally, the paper offers some recommendations on how to promote climate-smart paddy farming technologies.

### *B.Present Status of Climate Change in Sri Lanka*

Sri Lanka, which is an island state, is vulnerable to all identified impacts of climate change such as rise in land and sea surface temperature, sea level raising changes and the amount and pattern of precipitation. Sri Lanka has experienced a wide range of parameters of climate change such as a rise in temperature of 0.01–0.03°C per year, an increase in maximum and minimum temperature, a decrease in rainfall, increased intensity of rains, delays in on-set of monsoonal rainfall, erosion in coastal belt, landslides, and an increased frequency of extreme weather events, such as floods and droughts [12]. Analysis of long-term air temperature data has provided strong evidence that significant and systematic warming of the atmosphere has occurred in all climatic zones of Sri Lanka [13]. The rate of increase in temperature from 1961 to 1990 is 0.016°C per year [14], while the global average for the period 1956-2005 is 0.013°C per year [15], indicating a faster warming trend in the recent years in Sri Lanka. Mean (annual and seasonal) daytime maximum and mean (annual and seasonal) nighttime minimum air temperatures have both increased during the period 1960-2001 [16], [17]. The mean annual rainfall of the country has decreased by 144mm (7%) during the period 1961-1990 compared to the period 1931-1960 [18], [19].

The total annual rainfall in different parts of the country has shown different changing trends. In the Jaffna, Potuvil and Mullaitivu the rainfall has recorded an increase, while it has declined in all the other stations throughout the country [20]. In terms of the number of rainy days, except the Nuwara Eliya station, all the other stations recorded declining trends. An increase in the number of consecutive dry days and a reduction in the number of consecutive wet days have been reported [21]. Analysis of monthly and annual rainfall data from 1950 to 1989 has showed that the *El Niño* phenomenon reduced rainfall during the following year in all locations [13].

The intensity and frequency of extreme climate events (floods and droughts) have increased in recent times triggering an increase in natural disasters [21], [22].

### *C.Impacts of Climate Change on Paddy Cultivation in Asia*

Available projections in Sri Lanka [24] have indicated that climate change impacts can be significant in the dry zone, especially in the Northeast and the East, where some of the agriculturally intensive areas are located and are already experiencing water stress. The expected changes may lead to an increase in the *Maha* (main paddy season during North east monsoon) irrigation water requirement for paddy by 13-23% by 2050 compared to that of 1961-1990 period. Further, the observed and projected reduction in rainfall in the central highlands is likely to create conflicts between irrigation water supply and hydropower generation from the multipurpose Mahaweli scheme.

Scientists working on the impacts of climate change on the paddy growth have confirmed that an increase in spikelet sterility with increased spikelet temperature above 31-32°C and suggests that the impact of climate change on pollen sterility in rice should be a common occurrence in high temperature sub humid eco systems [24]. They have further said that the impact of climate change would be more on quality than the productivity of rice produced in the sub humid tropics. It has also been reported that the grain yield of paddy declined by 10% for each 1°C increase in growing-season minimum temperature in the dry season, whereas the effect of maximum temperature on crop yield was insignificant [25].

Although the total grain dry matter increased with elevated $CO_2$ by 69.6% in ambient temperature, the total grain dry matter has decreased with elevated temperature by 33.8% due to warming-induced floral sterility [26]. The same experiment has also shown that projected warming is likely to induce a significant reduction in grain yield of rice by inhibiting DM (*i.e.*, photosynthates) allocation to grain, though this may partially be mitigated by elevated $CO_2$. Similar results have been shown in [27], indicating that, for both dry and wet seasons, a beneficial increase in growth and yield with elevated $CO_2$ is possible for irrigated rice grown in a tropical environment. In addition, increases in $CO_2$ and/or temperature may also reduce protein content and overall nutritional quality.

According to a study carried out in Sri Lanka [28], rice under elevated $CO_2$ showed significantly greater (20% and 11% in the two seasons) radiation use efficiency (RUE) relative to ambient $CO_2$. Also the number of grains initiated and percentage of grains filled were significantly greater under elevated $CO_2$ resulting in final seed yields being 24% and 39% greater than the ambient. They have concluded that rice yields respond positively to increasing $CO_2$ even at the higher range of growing temperatures. Another study, the leaf net photosynthetic rate under elevated $CO_2$ had increased by 22–75 % in comparison to the ambient [29]. Further, it has shown that the leaf chlorophyll content increased significantly under elevated $CO_2$.

*D.Climate Change Adaptation*

According to Inter-governmental Panel on Climate Change (IPCC) [30], climate change adaptation is the initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Adaptations can be classified on the basis of adaptive responses to climate change, such as reactive (measures which are made by institutions, individuals, animals and plants as response) or anticipatory (carried out as preparations against potential effects), autonomous (adjustments which are occurring naturally or spontaneously as response) or planned (adaptations need conscious intervention) [31].

There are several major barriers to implementing climate change adaptation, such as environmental, economic, informational, social, attitudinal and behavioral constraints [24]. The IPCC has further recognized that there are significant knowledge and information gaps for adaptation as well as impediments to flows of knowledge and information relevant for adaptation decisions. The psychological and cognitive processes involved in different types of climate change adaptation have received attention of the researchers. The Food and Agricultural Organization has highlighted some important options for increasing the adaptive capacity of farming communities who face severe threats due to changing climate [33: 78]:

- "Bear the loss – accept reductions in area or productivity.
- Share the loss – distribute the impacts of reduced water resources to share reductions in area and productivity.
- Modify the threat – at an individual level, expand farm size and benefit from economies of scale; improve water use efficiency through better technology and management.
- Prevent the effects – for example increase water and input use.
- Change use – crop change, land-use change, mix of rain-fed and irrigated production.
- Research to find adaptations – improve crop productivity in higher temperatures and with greater moisture stress.
- Educate for behavioral change".

A study on the adaptation of paddy cultivation in the South Asian countries has identified a range of adaptive options such as; adjusting then planting dates, use of traditional varieties, site-specific nutrient management, alteration of farm management practices e.g. System of Rice Intensification (SRI), crop rotation, and Integrated Pest Management [34]. The rice farming methods such as intermittent irrigation, zero-tillage, use of bio-chars, and deep placement of urea, also would help mitigate the Green House Gas emissions from rice fields.

Harvesting rainwater and storage during higher rainfall seasons, especially in the dry and intermediate zones, is a viable adaptation option for utilizing available water resources throughout the year [23]. Wastewater reuse, increasing water use efficiency and change of allocation practices are some other adaptation options suggested. The provisions of rainwater harvesting systems to all households in drought-prone areas, and making it a prerequisite to receive drought relief are also suggested [35]. Renovating the existing tanks to store excess rainfall during the monsoons and devising methods to store and transfer excess rainfall in the wet zone to the dry zone would be some other available alternatives suggested.

There are number of new adaptive strategies available at the research level. The Rice Research and Development Institute (RRDI) of Sri Lanka has involved in developing technologies and appropriate rice varieties which respond positively to increased air temperature and humidity, increased atmospheric $CO_2$, moisture stress, increased salinity and, submergence. Short-term (low water consuming) rice varieties suitable for shorter growing seasons have already been developed and tested. Investigating the impact of increased temperatures, humidity and moisture stress on crops also had been suggested [23]. There is evidence that the dry zone farmers in the North-central province of Sri Lanka have adopted several short-term and long-term adaptive strategies related to crop rotation, adjusting planting time, changing over to short period crops and varieties and rainwater harvesting techniques [36].

It has been suggested to adapt broader scale changes such as partial shifting of present locations to areas projected to receive more beneficial rainfall, changing the planting time to suit altered rainfall onset times [37] and, crop diversification and shifting from rice to other field crops too are adaption strategies that would help the farmers [23]. It has been shown that under the elevated $CO_2$, the rice grain yield could be maximized by supplying sufficient Nitrogen fertilizer [26].

*E.Perceptions, Knowledge and Attitudes of Paddy Farmers on Climate Change*

Generally, people's understandings of climate change underlie their willingness to act, and to support public policies, in response to it. Achieving an appropriate understanding of climate change is difficult. The effects of climate change are uncertain and are place-specific due to geographic differences as well as differences in resources available for adaptation [38]. Creating the accurate understanding among the stakeholders of the scientific, political and economic complexity of climate change is highly challenging for communication [39].

Several studies undertaken so far in different parts of the world have revealed that the diverse national publics have not perceived these complex issues of climate change accurately, despite a growing trend to pay an increased attention by the mass media [40]-[44]. There is a serious lack of up-to-date studies, but the existing knowledge base provides evidence that especially in developing countries, many of which are likely to be severely affected, people are not sufficiently aware of the dangers and causes of climate change [45].

A study on farmers' adaptations to climate change in Limpopo River Basin of South Africa has shown that the farmers' perceptions of climatic variability were in line with climatic data records [46]. Although the farmers studied are well aware of climatic changes, only about 30 % have adjusted their farming practices to account for the impacts of climate change. The perceptions of local people on climate variability in the Mid-Mountain Region of Nepal were found to be in line with climatic data records [47]. However, in rural mid-hills of Chepang community in Nepal, only one-third of the respondents were able to perceive the changes in line with the recorded data [48]. They also found that access to information, and extension services are the most important factors facilitating climate change perceptions, while the formal education and engagement in non-farm income sources reduce the ability to perceive the climatic changes. There is widespread climate change in the Himalayas, where the farming communities of different altitudes vary in their level of climate change perceptions [49]. The traditional communities in Tibetan mountainous villages have perceived the causes of climate change as both material and spiritual phenomena [50]. This study has also shown that the majority of perceived spiritual reasons were linked to human misconduct, while some were morally neutral and more fatalistic, thus showing the lack of scientific awareness. Similar observations have been made in a survey conducted among arable crop farmers in Western Nigeria as: "Respondents (95%) were convinced that the vagaries of the climate are a sign of divine anger as there are many sinners in our mist and God is trying to punish us; like floods, with serious consequences" [51: 09].

A study on the climate change perceptions of apple farmers in Western Himalayas has shown that of climate change is perceived by knowledge of crop-climate interaction and by differential outcomes of apples associated with the changed conditions [52]. Having reviewed 19 empirical studies that evaluated the conservation impact of popular participation in forest management, a study has concluded that based on the local ecological knowledge people can assess changes in their environment. They also recommend refinement and validation of perception-based participatory methods in order to use them under diverse field conditions [53].

A comparative study about the farmer perception and adaptation to climate change of home gardening farmers in Sri Lanka, India and Bangladesh [54] has revealed that the respondents from three dry zone villages in Sri Lanka only 6.1% perceived both temperature and rainfall changes correctly, even though 53.4% and 21.6% correctly perceived the changes in environmental temperatures the amount of rainfall respectively. In the case of Bangladesh, none of the respondents have correctly perceived the changes observed in temperatures and rainfall. In the case of India too, no respondent has perceived that the onset of rainfall has changed over the period, although the actual data clearly show such an event in the recent past.

Another public perception survey conducted in all major climatic regions in Sri Lanka has shown that majority of the public have perceived changes in the climate *i.e.* increased rainfall intensity (60%), change of rainfall pattern (70%), increase in the dry season (63%), and increased air temperature (80%). However, the majority (58%) of the respondents were unaware of the concept of global climate change [55].

An examination of the perception of the paddy farmers and adjustment of their farm management practices, in the dry zone of Sri Lanka has revealed that during the last few decades, the pattern of rainfall has significantly changed and the farmers have observed the changes in the climate affecting their livelihood [56]. The increase in average temperature combined with decreased rainfall has forced them to change their traditional paddy farming to shifting (*Chena)* cultivation. The farmers in the low country intermediate zone of Ratnapura district in Sri Lanka have perceived that the length of dry spells and the temperature have increased in the area [57].

Although some research has been done on the farmers' perception, as well as adaptation related to climate change of the small scale rain-fed paddy farming communities in the dry zone of Sri Lanka, very little is known about the perceptions of the paddy farmers in the mid elevation districts in Sri Lanka. Therefore, an empirical investigation was conducted with the objectives of: Assessing the status of climate change and the perceptions of paddy farming community in the mid country wet and intermediate zones. The actual meteorological data from the selected locations were analyzed to find out the pattern of changes in rainfall and temperature, and compared with the perceived changes of the farmers. The knowledge and attitudes of the farmers towards the causes and effects of climate change on paddy cultivation was also measured.

From the foregoing discussion it is clear that the climate change is one the most difficult to understand phenomena faced by the farming communities today. Effective interventions for adapting to climate change require changes in the attitudes and behaviors of a large majority of farming population. In order to achieve these complementary changes in organization, which provide education, incentives, and institutional support are necessary. Farming communities are finding it increasingly difficult to adapt climate-smart technologies as they are often excluded from the policy process by those in power and authority, who often used to manipulate the policy process for their political or economic benefits [58]. In the light of such a complex scenario it is very important to understand both scientific and psycho-social issues related to major agricultural systems so that the timely interventions to mitigate and adapt to the realities of climate change by all the stakeholders.

## II. Methodology of the Case Study

### *A. Study Area*

Kandy district (Located in North Latitude $60.56^0$ to $70.29^0$ and East Longitude $80.25^0$ to $80.00^0$), which is covering both the wet and intermediate climatic zones of the mid country was selected for the study. The elevation of the Kandy city is 465 meters above mean sea level and the annual rainfall is 1840 mm and the mean temperature varies between $20\text{-}22^0$ C, while the humidity varies from 70% to 79%. Of the total land area of $1940km^2$ of the Kandy district 8.5% is cultivated in paddy, mostly under rain-fed condition, except the Minipe area, which receives irrigation water from the Mahaweli scheme.

Two Divisional Secretariat Divisions (DSDs), viz. Yatinuwara (mid country wet zone) and Kundasale (mid country intermediate zone) were selected as they are representative of the two agro-climatic zones and also because accurate meteorological data from these two locations were available in the Department of Agriculture. There are 95 Grama Niladhari divisions (GNDs) (lowest level administrative units in the country) in Yatinuwara DSD, which covers a land area of $70km^2$. The corresponding numbers for the Kundasale is and 80 GNDs and $86km^2$ respectively. Altitudes of these two DSDs vary between 500-600m and 420-780m for Yatinuwara and Kundasale respectively. The extent of paddy lands in Yatinuwara and Kundasale Divisional Secretariats divisions were approximately 1600ha and 1061ha respectively [59].

### B. *Collection of Primary Data*

A sample of 64 farmers (32 from each DSD) was selected using multistage sampling method for the questionnaire survey. The main variables measured included demographic variables of the respondents such as age, education, and income, and the perception, knowledge and attitudes on climate change causes and the effects on paddy cultivation, and the level of adaptation of appropriate technology. Primary data were collected through interview schedules by conducting a social survey.

The main secondary data collected were the daily rainfall data and monthly mean maximum and mean minimum temperature data from 1977 to 2010. Data recorded at the meteorological stations at the School of Agriculture, Kundasale (for Kundasale DSD) and Horticultural Research and Development Institute, Gannoruwa (for Yatinuwara DSD) were collected from the Natural Resource Management Centre, of the Department of Agriculture in Sri Lanka.

### C. *Data Analysis*

Data was analyzed by using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel software package. Statistics tests such as correlation (Spearman's rho) and independent T sets were used to analyze data. In analyzing the daily rainfall data, the onset and the withdrawal were determined based on the methodology proposed by Punyawardena, [12]. Accordingly, the onset of rainfall was defined as a spell of at least 30mm per week in three consecutive weeks after pre-specified week for the *Maha* (Standard week 35) and *Yala* (South west monsoon season) (Standard week 9) seasons. If three weeks criterion is not satisfied, the condition was reduced up to two consecutive weeks with rainfall equal to or greater than 30mm. Similarly, the first occurrence a long dry spell two consecutive weeks with less than 30mm of rainfall after a pre – specified week for *Maha* (Standard week 50) and *Yala* seasons (Standard week 16) was defined as the end of the season. Length of the season was taken as the number of weeks between the onset of the season and onset of the season.

## III. Results and Discussion

### A. *Demographic Characteristics of the Respondents*

All the respondents were involved with paddy farming, 87.5% among them were heads of the households and 9.4% were spouses of the household head. There were 28.1% & 37.5% household heads involved in fulltime paddy cultivation from Yatinuwara and Kundasale respectively.

#### 1.Age Distribution

The mean age of the respondents was 57 years. There were 53% and 44% respondents aged 60 years or over in Yatinuwara and Kundasale respectively. These proportions are significantly higher than the national average of the working population (14.6%) and it indicates that younger generation is moving away from paddy farming [60].

More than 90% of the respondents have been living in the corresponding areas for 30 or more years in both DSDs. Majority (90%) of the respondents, had farming experience of 20 years or more in Kundasale, while the corresponding value for Yatinuwara was 78%.

#### 2.Education Level

The majority (75%) of the respondents from Yatinuwara had had education up to G.C.E. (Ordinary Level) or higher while the corresponding value for Kundasale was 58%. The Yatinuwara is a semi-urban area located in close proximity to the Kandy city where there is better access to schools and higher education institutes compared to Kundasale, which is located about 15km away from the urban center.

#### 3. Income

Average income of a household head in Yatinuwara was LKR 14,780 and it was LKR 16,760 in Kundasale. The possible reason might be the more commercialized farming system in Kundasale characterized by the cultivation in both *Maha* and *Yala* seasons compared to predominant subsistent paddy farming system with low income non-farming activities prevailing in Yatinuwara.

### B. *Climate Change of the Study Area*

The mean temperature of Yatinuwara was below that of Kundasale in 1970s. However, it has increased gradually and had gone slightly higher than that of Kundasale within last 10-15 years. Yatinuwara is also getting higher rainfall than the Kundasale.

The change of temperature during the last 33year period showed that both mean annual maximum and minimum temperature data have shown increasing trends in Yatinuwara. However, there was no significant changing trend in the mean annual maximum temperature in Kundasale, (Fig. 1).

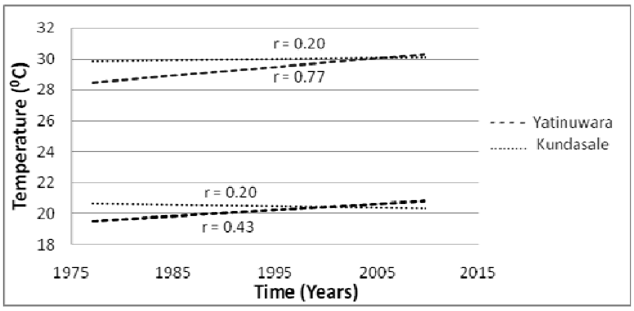


Fig. 1 Trend lines of change in mean annual maximum and minimum air temperatures during 1977 - 2010

However, liner trend line of the mean annual maximum temperature in Yatinuwara (r = 0.77) showed a strong fit to a liner trend line while the liner trend line of mean annual minimum temperature in Yatinuwara (r = 0.43) had a weak fit to a liner trend line. Both the number of rainy days and the rainfall has shown increasing trends in both Yatinuwara and Kundasale (Table I). The trend line for number of annual rainy days and the annual rainfall show a very weak fit except the number of rainy days in Kundasale (r=0.45).

TABLE I
SUMMARY OF CHANGE IN ANNUAL RAINFALL AND RAINY DAYS DURING 1977-2010

| Climatic parameter | DSD* | Max | Min | Mean | SD | Liner trend | r value |
|---|---|---|---|---|---|---|---|
| No. of annual rainy days | Y | 181.0 | 72.0 | 151.3 | 23.9 | +0.599 | 0.29 |
| | K | 160.0 | 84.0 | 137.4 | 15.4 | +0.641 | 0.45 |
| Annual rainfall mm. | Y | 2842.2 | 1242.8 | 1961.3 | 352.8 | +4.683 | 0.15 |
| | K | 1818.8 | 959.9 | 1440.3 | 207.5 | +2.952 | 0.15 |

* Y= Yatinuwara K = Kundasale

The onset of *Maha* rains (North-east monsoon) has shown almost no change in Kundasale, while a slight advancing trend (early onset) in Yatinuwara (Table II). However, the onset of *Yala* rains (South-west monsoon) has shown a delaying trend (late onset) in both locations. The duration of *Maha* rains has shown increasing trend in both DSDs, while duration of *Yala* rains had shown no change in Yatinuwara, but a decreasing trend in Kundasale (Table II).

The meteorological data only on the onset of *Yala* rains in both Yatinuwara (r = 0.33) and Kundasale (r = 0.32) showed at least a weak fit of data to a liner trend line (Table II), while the other changes did not show a clear liner trend.

The total rainfall in *Maha* season has shown a slight increasing trend in both DSDs. However, in *Yala* season in Yatinuwara it has decreased significantly, while in Kundasale it has increased. Similar findings has been reported in a previous research undertaken in the mid country wet zone where there was a high variability in *Yala* compared to *Maha* with respect to the onset and withdrawal of rainfall observed during 1976-2008 [61].

TABLE II
SUMMARY OF CHANGE IN MAHA AND YALA RAINS DURING 1976-2010

| Climatic parameter | DSD | Max | Min | Mean | SD | Linear trend | r value |
|---|---|---|---|---|---|---|---|
| Onset of *Maha* rains (Standard weeks) | Y | 47.0 | 36.0 | 39.6 | 2.6 | -0.049 | -0.19 |
| | K | 46.0 | 36.0 | 40.0 | 3.0 | +0.019 | 0.06 |
| Duration of *Maha* rains (No. of weeks) | Y | 19.0 | 8.0 | 13.0 | 2.7 | +0.051 | 0.19 |
| | K | 20.0 | 7.0 | 12.9 | 3.0 | +0.062 | 0.23 |
| Rainfall in *Maha* (mm) | Y | 1284.9 | 363.9 | 792.7 | 218.1 | +1.793 | 0.08 |
| | K | 1183.8 | 331.8 | 654.5 | 207.3 | +1.170 | 0.06 |
| Onset of *Yala* rains (Standard weeks) | Y | 24.0 | 10.0 | 15.3 | 3.5 | +0.115 | 0.33 |
| | K | 22.0 | 10.0 | 15.2 | 3.2 | +0.095 | 0.32 |
| Duration of *Yala* rains (No. of weeks) | Y | 22.0 | 6.0 | 12.4 | 3.7 | - | < 0.00 |
| | K | 18.0 | 6.0 | 9.8 | 2.9 | +0.052 | 0.19 |
| Rainfall in *Yala* (mm) | Y | 1267.6 | 260.7 | 620.5 | 220.9 | -0.689 | -0.03 |
| | K | 620.8 | 141.6 | 343.9 | 131.0 | +0.328 | 0.00 |

### *C. Comparison of Perception of Respondents with Meteorological Data*

Majority of the respondents have perceived a climate change as a whole in both Yatinuwara (81%) and Kundasale (84%). Majority of the respondents in both Yatinuwara (81%) and Kundasale (75%) also have indicated that the climate has become less predictable in recent years.

#### 1.Perceived Time Duration for the Changes in the Climate

Perceived time duration of the respondents, who have perceived any kind of change (*i.e*. increased, decreased or changed irregularly) in climatic parameters are shown in Table III.

TABLE III
PERCEIVED TIME DURATIONS FOR THE CHANGES IN THE CLIMATE

| Climatic parameter | DSD | Percentage of respondents | | |
|---|---|---|---|---|
| | | During last 5 years | During last 10 years | more than 10 years |
| Annual day temperature | Y | **53.8** | 26.9 | 11.5 |
| | K | **41.4** | 20.7 | 37.9 |
| Annual night temperature | Y | **36.8** | 31.6 | 15.8 |
| | K | **40.9** | 18.2 | 31.8 |
| Annual rainy days | Y | **55.6** | 14.8 | 14.8 |
| | K | **35.7** | 17.9 | 32.1 |
| Annual rainfall | Y | **55.0** | 30.0 | 0.0 |
| | K | 38.9 | 16.7 | **44.4** |

It is clear that farmers in both DSDs have perceived the changes (*i.e.* increasing) in temperatures as a recent phenomenon occurred during last five years. But, with regards to the rainfall, Farmers in Kundasale have perceived changes in climate for a long time. In contrast, Majority of the farmers in Yatinuwara have perceived the changes corresponding to the data for the last five years. More farming experience of farmers in Kundasale than the farmers in Yatinuwara may be one of reasons for this difference. Also, as a semi dry area, which is receiving low and irregular rainfall with water scarcity, farmers of Kundasale may have been more sensitive adverse climatic conditions or impacts for relatively a longer time.

2.Comparison of Perception of Temperature with Meteorological Data

Perception of the majority of the respondents in both locations has been that the day temperature (maximum day temperature) has increased (Table IV). This perception is better reflected with the actual short-term changes shown in Fig. 2 than the long term changes (Fig. 1).

TABLE IV
SUMMARY OF THE PERCEPTION OF DAY AND NIGHT TEMPERATURES

| Climatic parameter | DSD | Percentage of Respondents | | | |
|---|---|---|---|---|---|
| | | Increased | Decreased | Changed Irregularly | Not changed |
| Annual day temperature | Y | **59.4** | 18.5 | 3.1 | 9.4 |
| | K | **78.1** | 0.0 | 12.5 | 9.4 |
| Annual night temperature | Y | **37.5** | 12.5 | 9.4 | 25.0 |
| | K | **43.8** | 9.4 | 15.6 | 18.8 |

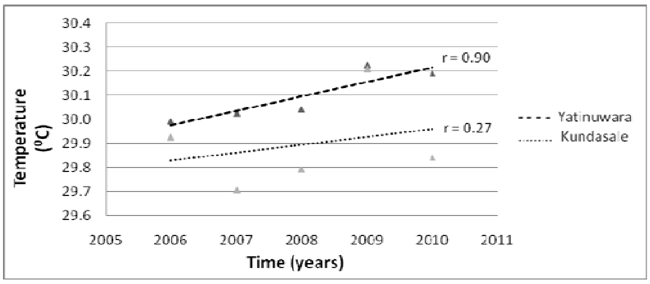


Fig. 2 Trend of change in mean annual maximum air temperatures during 2006 -2010

The majority had not perceived an increase in the night temperature (minimum day temperature). This is reflected more clearly in Yatinuwara with the actual changes of short-term minimum temperature changes as shown in Fig. 3.

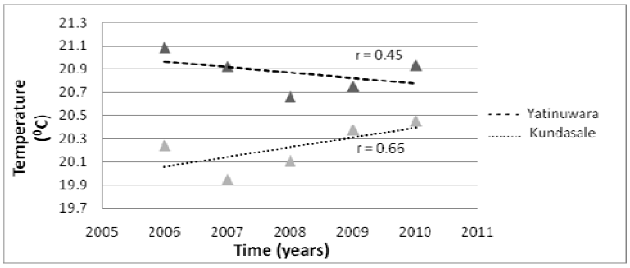


Fig. 3 Trend of change in mean annual minimum air temperatures during 2006 – 2010

3. Comparison of Perception of Annual Rainfall and Rainy Days with Corresponding Meteorological Data

TABLE V
SUMMARY OF PERCEPTION OF THE ANNUAL RAINFALL AND RAINY DAYS

| Climatic parameter | DSD | Percentage of Respondents | | | |
|---|---|---|---|---|---|
| | | Increased | Decreased | Changed Irregularly | Not changed |
| Annual rainy days | Y | **59.4** | 21.9 | 3.1 | 3.1 |
| | K | 3.1 | **78.1** | 6.3 | 9.4 |
| Annual rainfall | Y | 28.1 | **34.4** | 0.0 | 18.8 |
| | K | 3.1 | **53.1** | 0.0 | 12.5 |

Perception of annual rainy days by the majority in Yatinuwara (Table V.) is in line with the meteorological data for past five years (Fig. 4), which showed a strong fit of data to a increasing liner trend line ($r = 0.71$, $p = 0.18$). Corresponding data for Kundasale showed no significant increase ($r = 0.06$, $p = 0.93$), contrasting to the majority (78.1%) of the farmers' perception of a decrease.

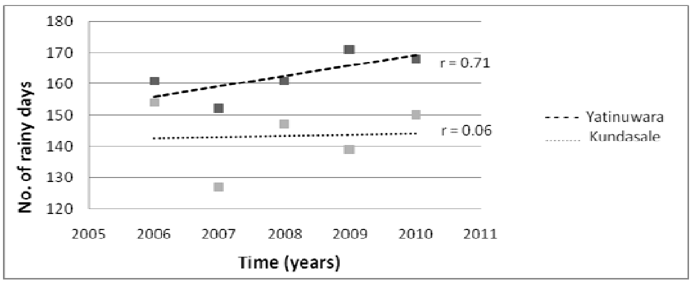


Fig. 4 Trend of change in annual rainy days during 2006 – 2010

*D. Perceived Impacts form the Changes in the Climate*

The respondents in Yatinuwara had found no significant impact so far from the increased temperature. However, in Kundasale, 39% of the respondents have indicated that they find an increasing scarcity of irrigation water. The changing rainy days has been perceived to create grain sterility (22.7%) and water scarcity (33.3%) by Yatinuwara and Kundasale farmers respectively. The changes in the onset of rains have been perceived to cause disturbances to timely farm operations by 20.0% and 38.9% of famers in Yatinuwara and Kundasale respectively.

*E. Perception of the Extreme Weather Events*

TABLE VI
PERCEPTION OF THE EXTREME WEATHER EVENTS

| Climatic parameter | DSD | Percentage of Respondents | | | |
|---|---|---|---|---|---|
| | | Increased | Decreased | Changed Irregularly | Not changed |
| Frequency of droughts | Y | 16 | **53** | 0 | 28 |
| | K | **50** | 12 | 0 | 34 |
| Frequency of floods | Y | 34 | **37** | 6 | 22 |
| | K | 6 | **12** | 6 | **75** |

Since there were less incidents of flood in Kundasale, the majority have perceived no change in it (Table VI).

Majority of the respondents have perceived an increase in pests (89.1%), diseases (76.6%) and weeds (81.3%) in their paddy fields. Respondents who have perceived an increase in pests mentioned that rats (70.2%), wild boar (54.4) and Leaf rolling caterpillar (22.8%) as the major pests that cause increased crop damage. *Echinichloa glabrescens* (Bajiri) (55.8%) and *Fimbristylis miliacea (*Kudametta) (17.3%) were the major weeds observed to have been increased.

*F. Paddy Farmers Knowledge and Attitudes on Climate Change*

1. Knowledge on Adaptation Strategies of Climate Change

The respondents mostly believed that the causes for climate change as the destruction of forests (39.1%) and constructions of houses, buildings, infrastructure etc. (15.6%). The subsistent farmers are mostly interacting with the nature and they consider themselves and plant kingdom as inseparable parts the weather/climate as interrelated components of the nature therefore, they simply attributed the changes in climate to the destruction of the natural forest biomass which is also having links with weather cycle, even thought they could not explain the scientific intricacies of the relationships.

Knowledge on adaptation strategies to the climate change was measured using seven statements and the weighted score given for the knowledge on adaptation strategies to the climate change was ranged from -10.5 to 10.5. Weights given are shown in Table VII.

TABLE VII
WEIGHTS GIVEN FOR KNOWLEDGE ON DIFFERENT ADAPTATION STRATEGIES

| Knowledge component | Weight | Range | Weighted Score |
|---|---|---|---|
| Changing the planting time | 2 | - / + 2 | -4 /+4 |
| Crop rotation | 0.5 | - / + 2 | -1 /+1 |
| Crop diversification | 0.25 | - / + 2 | -0.5/+0.5 |
| Rain water harvesting | 0.5 | - / + 2 | -1 /+1 |
| Soil moisture conservation | 1.5 | - / + 2 | -3 /+3 |
| Availability of drought resistant varieties | 0.5 | - / + 1 | -0.5 /+0.5 |
| Availability of flood resistant varieties | 0.5 | - / + 1 | -0.5 /+0.5 |

The mean score for the knowledge on adaptation strategies to climate change of the whole sample was +2.8, which is indicating a positive knowledge on climate change. However, the mean knowledge score of farmers in Kundasale (+4.3) was significantly higher than the mean of Yatinuwara (+0.7) (t = -2.678, Sig. = 0.010).

2. Attitudes on Climate Change

Attitudes of respondents on climate change were measured under three categories as attitude on anthropogenic causes, attitude on severity of impacts and the attitude on Need for adaptation. Each of these components ware measured by three statements in the Likert scale and the score given for each component ranged from -6 (-2 x 3) to +6 (2 x 3). A composite scale by averaging three attitude components was developed to measure overall attitudes on climate change.

The mean attitude of the whole sample on anthropogenic causes of climate change was negative (-1.1) suggesting that the majority have not been adequately informed about the real causal agents of climate change. The widely held belief among some farmers that the climate is natural phenomena and it is beyond the influence of human beings, and the lack of knowledge of farmers about the contribution of paddy cultivation for the $CO_2$ emissions might be possible reasons for this negative attitude. The mean attitude on severity of impacts of climate however, was highly positive (+3.9) since the farmers of the both DSDs have experienced the negative impacts of bad weather in recent years. The mean attitude on the need for adaptation to the climate change also was positive (+2.1). The overall attitude score of farmers in Kundasale (+2.1) was significantly higher than that of Yatinuwara (+1.1) (t = -2.46, Sig. = 0.018). This could be mainly due to the fact that the majority of the Yatinuwara farmers were part-time farmers who were less sensitive to the changes in farming circumstances.

*G. Adopting of Adaptation Strategies to the Climate Change Impacts*

Farmers in both DSDs were using strategies (Table VIII) that enhance their ability to face the impacts of climate change. Crop rotation is regularly done by the farmers in Kundasale, where the water is often inadequate for paddy cultivation in *Yala* season. Diversification into other crops is done to a lower extent in both DSDs. Rainwater conservation is only practiced in Kundasale as small tanks and *pathaha*(in-situ water harvesting structures) which are located in the upper part of the paddy field area *(Yaya*). Soil moisture conservation is done mainly through applying straw to the paddy field and the main incentives behind this are to add nutrients to the soil and also to receive government fertilizer subsidy. However, the practice of the adding straw to the paddy field has recently decreased since it is believed to be enhancing the spared of leptospirosis (rat fever).

TABLE VIII
LEVEL OF ADOPTION OF MAJOR ADAPTATION STRATEGIES

| Adaptation strategy | | Percentage of respondents | | |
|---|---|---|---|---|
| | | Yatinuwara | Kundasale | Overall |
| Changing the paddy variety | | 87.5 | 100 | 93.75 |
| Changing the planting time | | 21.9 | 65.6 | 43.75 |
| Crop rotation | | 12.5 | 87.5 | 50 |
| Crop diversification in *Yala* season | | 12.5 | 21.9 | 17.2 |
| Water conservation | Rain water harvesting | 0 | 21.9 | 10.95 |
| | Soil moisture conservation | 34.4 | 59.4 | 46.9 |

Considerable (44%) percentage of the respondents indicated that they change the planting time according to the changes in the rainfall. This finding is comparable to the home gardening research undertaken in Sri Lanka, India and Bangladesh [54]. Majority (88%) of the respondents are practicing crop rotation in *Yala* season in Kundasale, similar to the findings of previous research undertaken in the dry zone where the farmers have shown a tendency to switch over to *Chena* (shifting) cultivation, instead of paddy due to uncertain pattern of rainfall, particularly the *Yala* season [56].

The overall of level of adaptation was estimated by a composite index developed according to level adaptation by each respondent and score given ranged from 0 to + 20. Each respondent was categorized into three levels as low, medium and high by using half standard deviation method. The mean score for the level of adoption of adaptation strategies to the climate change of the whole sample was medium (9.5).The level of using of adaptation strategies of farmers in Kundasale (mean = 12.3) was significantly higher than that of Yatinuwara (mean = 6.7) (t = -4.29, Sig. (2-tailed) = 0.000).

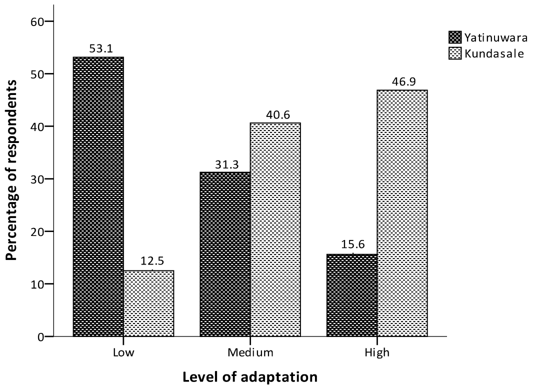


Fig. 5 Overall level of adoption of Adaptive main strategies

The low level adaptation in Yatinuwara could be due to their low level of engagement with farming as many of them were part-time farmers.

Majority of the respondents (87.5%) in Kundasale had medium to high level of using adaptation strategies to climate change impacts (Fig. 5) and this results also fall closely to the findings of the dry zone home gardening research referred earlier where the respondents changed planting dates of crops, introduced new technologies or either changed agronomic activities or used soil and water conservation measures in home gardens [54]. The overall level of adoption of adaptation strategies by the farmers was medium. However, this level of adaptation is higher than that of similar studies that has conducted in Nepal [47] and South Africa [46].

### *H. The Interrelationships between Independent and Dependent Variables*

The level of adoption of adaptation strategies by the farmers were strongly correlated with their knowledge ($r^2 = 0.498$, p = .000) and attitudes ($r^2 = 0.316$, p = .021).

TABLE IX
ASSOCIATIONS BETWEEN SOCIO-ECONOMICAL VARIABLES WITH KNOWLEDGE, ATTITUDES AND LEVEL OF ADAPTATION

| Independent variable | Dependent variables | | | | | |
|---|---|---|---|---|---|---|
| | **Overall Attitude on** climate change | | **Knowledge on** climate change **adaptation** | | **Level of** climate change **adaptation** | |
| | **r** | **Sig.** | **r** | **Sig.** | **r** | **Sig.** |
| Age | - 0.252 | 0.069 | - 0.067 | 0.633 | - 0.108 | 0.398 |
| Education | 0.355** | 0.009 | 0.012 | 0.935 | - 0.045 | 0.722 |
| Income[1] | 0.461** | 0.001 | 0.115 | 0.413 | - 0.018 | 0.889 |
| Period of settlement | - 0.107 | 0.445 | 0.029 | 0.834 | 0.029 | 0.819 |
| Farming experience | - 0.055 | 0.694 | - 0.123 | 0.380 | 0.051 | 0.690 |

** Significant at the 0.01 level
[1] Income of the head of the household

The education level and the income of the heads of the households showed a significant positive correlation with the overall attitudes (Table IX). Education level of the responds also had a significance positive correlation with the income of the head of the household, thus showing that the farmers with good education and income have a higher adaptive capacity.

There was a negative relationship (significant at the 0.10 level) between the age of the respondents and the attitude on adaptation to the climate change. The novelty of the climate change phenomenon, the less faith on agriculture extension officers' opinions, the resistance to change established farming practices, and the sense of fatalism could be the possible reasons for the older respondents to have more negative attitude of climate change adaptation.

## IV. Conclusions and Recommendations

### A. Conclusions

The various research studies referred in this study have confirmed the unprecedented changes of the climate and its impacts to crop farming in the tropics. The findings of the empirical investigations of this study also confirmed that temperature and rainfall patterns of the locations studied have changed over time. The mean annual maximum temperature in Yatinuwara showed a stronger liner increasing trend. Both the number of rainy days and the rainfall have shown increasing trends in both Yatinuwara and Kundasale. Theonset of *Yala* rains in both Yatinuwara and Kundasale has also been changing over time.

The farmers' perceptions were compared with the meteorological data and possible reasons for discrepancies were identified. The comparison showed that the farmers' perceptions were more in line with the short-term actual changes. Farmers' perception of day temperature in both DSDs are in line with the corresponding meteorological data while, only the perception of farmers in Kundasale on night temperature was in line with the corresponding meteorological data. Only the perception of on annual rainy days by the famers of Yatinuwara was in line with the corresponding meteorological data. However, the perception of the majority of the famers in both DSDs on annual rainfall was wrong.

The differential perception by the famers of this study, as well as in various other studies quoted, show clearly the difficulty faced by the farmers to properly comprehend the changing trends of the climate. In most cases the rural famers seemed to have had no organizational support system of getting the local weather data and forecasts in away to help them make appropriate farming decisions. The gradual deterioration of the close sensitivity that the traditional farmers maintained with their natural environment is also apparent, when the farmers' knowledge of adaptation strategies, overall attitudes, and the level of adoption of adaptation strategies to the climate change were assessed.

The knowledge on adaptation strategies to the climate change, overall attitudes on climate change and the adoption of adaptation strategies among Kundasale farmers were significantly higher than those of Yatinuwara. However, the attitude on anthropogenic causes of climate change was slightly negative.

The overall use of the adaptation strategies for the climate change impacts was medium among the respondents. A majority of the respondents are changing the paddy cultivar/variety that they cultivate. Changing the planting time and soil moisture conservation were medium among the respondents, while very low percentage of respondents were adopting rain water harvesting strategies.

### B. Recommendations

In the context of sustainable development of developing countries such as Sri Lanka, climate change adaptation should be conceived more as a process of transformation, which encompasses not only the bio-physical and technological systems, but also the social value system, legislative and bureaucratic adjustments together with financial institutions to facilitate the community level changes [62].

Increasing the resilience and reducing the vulnerability to the ever-increasing challenges of climate change is an unprecedented challenge faced by all stakeholders and particularly those involved in the of the paddy sector. The policy makers have acknowledged the importance of climate change adaptation by being among the first few countries to ratify the UNFCC. However, this study shows that the grass root level scenario provides little evidence that paddy farming communities are ready to manage the ground realities of climate change. According to IPCC [32], vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. The growing evidence suggests that too often adaptation is imagined purely in a technological domain. This study too has basically looked into the technical aspects of climate change with little insight to socio-psychological issues. More in-depth studies are therefore required to understand the adaptive capacity of different farming communities.

In order to make informed decisions on changing farming systems a further in-depth analysis of meteorological data is recommended to figure out the current status of climate change and also to be able to predict the future trends in different climatic zones of Sri Lanka. It is encouraging to see that the farmers are beginning to take the climate change seriously. Yet the present level of awareness and adaptations are highly inadequate. Therefore, it is also recommended to develop and implement strategies to communicate the past trends and the predictions of climate change correctly to the farmers and other stakeholders enabling them to make more accurate decisions.

It is essential to formulate communication strategies and conduct climate smart-extension and training programs to increase awareness, change attitudes and, motivate farmers towards important adaptation strategies, especially the promising technologies that have slow diffusion rates. There could be many others factors and attributes of the farmers affecting as incentives or barriers for changing behavior of farming communities, and hence, it is recommended to study them further in relation to different farming circumstances and use their cause and effect relationships in developing adaptation strategies.

The sustainable development of agricultural sector could only be achieved by integrating climate change adaptation into national development policies and ensure that they are implemented at national, regional and local levels [63]. Therefore, timely need of an integrated and collaborative approach involving state, private sector, civil society and farmer-based organizations to make the Sri Lankan agriculture 'climate-smart' cannot be overemphasized.

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