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# Effects of Adaptation to Climate Change on Technical Efficiency of Paddy Farmers in Panamaram

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**Abstract**

*Growing body of scientific literature published by the reports of the Intergovernmental Panel on Climate Change (IPCC) undoubtedly states that ongoing climate change is real and anthropogenic. Every sector of the economy will be adversely affected by ongoing climate change; however, immediate effects are being felt on agriculture sector as it is the man-made adjacent to the natural ecosystem. Although, mitigation and adaptation are the two-policy response to climate change, vulnerability of the agricultural system to climate change may be lessened to a large extent by increasing adaptation capacity of the agriculture to climate change. An attempt is made to understand efficiency effects of coping strategies and adaptation practices of Panamaram paddy farmers to climate change in Wayanad district of Kerala. Panamaram is one of the four Community Development Block of the Wayanad District of Kerala State of India, has largest concentration of production and area under paddy. Majority of the farmers are small and marginal and practices paddy cultivation only once in a year on their unirrigated plots. Technical efficiency of farmers coping and adapting to climate change is investigated using stochastic frontier production function approach. Based on random sample of 138 paddy farmers, study found that efficiency effects of adaptation strategy of the paddy farmers is more effective compared to copingstrategies. In response to different climatic anomaly, especiallyirregular rainfall pattern and incidents of flood, majority of the farmers resort to delay in sowing as an important coping strategy. Whereas farmers in long term end in view adopt changes in the cropping pattern as an important adaptation practice to climate change. Therefore, study suggest importance of adaptation practices and coping strategies to climate change in farm level planning.*

**Keywords**. Climate change; Paddy cultivation; technical efficiency; stochastic frontier; climate change adaptation, coping strategies.

## Introduction

The agricultural sector is at the heart of the economies of the less developed countries (FAO, 2002). However, the importance of this sector in context of less developed countries reveals decreasing contribution of agriculture to gross domestic product on one hand and increasing dependance of growing population in agriculture on the other(Annemarie, 2015). With reference to Indian economy, when more than 70 per cent rural households depend on agriculture and provides employment to over 60 percent, however, contribute only around 17 percent to gross domestic product (Narasimha et al, 2010).Moreover, recently central role of agriculture in the growth and development process has been challenged due to many reasons. There is policy, technological and environmental related fatigue which constraints agriculture to realizes its full potential.

Intergovernmental Panel on Climate Change (IPCC) in its major assessment reports unequivocally document the presence of climate change. Major perceived realities with climate change include melting of polar and mountain ice caps, resultant sea level rise and drowning of coastal areas, irregular rainfall pattern and high degree of average global temperature, etc. (IPCC 2014) in addition to extreme climatic events such as drought and flood. Developing country where majority of population depends on agriculture for livelihood, ongoing climate change makes agriculture highly vulnerable (FAO, 2007), and hence food security of the already impoverished population will be adversely affected. Against this backdrop offuture changes in the climate, adaptation to climate change perhaps an important policy response to climate change.

Mitigation and adaptation are the two important policy response to deal with the impacts of climate change (IPCC, 2001, Tol. R.S.J, 2005). Mitigation is ananthropogenic intervention, at individual, national and global scale to reduce the sources or enhance the sinks of greenhouse gases. (2014 IPCC 5^TH AR). It is the notion of limiting or controlling emissions of greenhouse gases so that the total accumulation is limited. In mitigation, its impacts are felt at the global and for long term. Whereas adaptation involves adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. It is the notion of making changes in the way we do things to respond to changes in climate. However, adaptation option has distinct advantage over mitigation because adaptation benefits are felts at the local level and can be for the long run.

**Theoretical Structure**

There are some studies with reference to foreign countries attempt to bring out relationship between climate variability and technical efficiency using different methodology. Amin W Mugera, et al. (2012), investigated the impact of climate variability on the production efficiency of farms in Kansas of U.S. The effects of temperature and precipitation are modelled under different stochastic production frontier specification and impact of climatic variability on total farm income, crop income and livestock income using a fixed effects panel regression model. The study found that climate variability significantly affects mean output elasticities with respect to input, return to scale, and technical efficiencies. Purchased inputs are more sensitive to climate variability than capital and labor.

Deep Mukherjee et al, (2012), in a study focuses on the potential impact of heat stress on milk production efficiency for a sample of dairy farms from the south-eastern US. Econometric models developed in the study are useful to quantify gross benefits expected from adaptation to climatic conditions represented by the Temperature Humidity Index (THI) and alternatively by the Equivalent Temperature Index (ETI). Stochastic production frontier analysis is used to measure technical efficiency for an unbalanced panel of 103 dairy farms located in Florida and Georgia. Five alternative model specifications are evaluated. The results reveal that both THI and ETI have a significant nonlinear negative effect on milk production. The climatic indexes when incorporated in the frontier specification absorb some of the output shortfall that otherwise would be attributable to inefficiency. The results also indicate that using fans combined with sprinklers is an effective adaptation to offset output losses stemming from heat stress conditions.

Muhammed Fauzi Makki et al. (2012),and Sabrina Auci et al.(2014) studies effects of climatic factors on technical efficiency is analyzed using stochastic frontier analysis, however particular adaptation practices specific to climate change which influences the efficiency looked into. Besides climatic factors, socio-economic variables in consideration of climate change at different level may also influences the technical efficiency of the agricultural production also overlooked in their studies.

Tanah Tam Ho et al. (2019),using propensity score matching approach, shows that adaptation to climate change in the form of climate smart agriculture participation increased the technical efficiency of the rice farmers by 13-14 percent more relative to those of the non-adapters. K. Vijayasarathi et al., (2015), studied determinant of climate adaptation technology and its impact on technical efficiency of production of major crop production using both multi-nominal logit model, and stochastic frontier production function. Study found adoption of technology to adaptation to climate variability significantly increases the technical efficiency in crop production whereas, lack of finance, lack of knowledge about the technology and high cost of adaptation are the major constraints for the farmers' adaptation to climate change.

Based on stochastic frontier analysis, there are few emerging literatures that attempt to examine the effects of adaptation strategies to climate change on technical efficiency of the agriculture. Important strategies to adjust with climate change include multiple cropping, land fragmentation, multiple planting dates, mulching and cover cropping (M.A Otitoju et al. 2014), improved irrigation facilities (Lisandro Roco et al.2017), soil conservation (Mohamud Salat et al. 2018), crop diversification, land fragmentation, use of improved verities and multiple planting dates (Rufus S.O 2020), row planting, changing planting date, mixed farming, refilling, and intercropping (Willian A et al. 2021). While some of strategies are adopted by farmers for long term end in view whereas some are coping strategies which have focus on short term benefits. Nostudy explicitly demarcated specific strategies undertaken in agriculture which are either coping strategies or adaptation strategies. The present study is an attempt to understand effects on technical efficiency of both coping and adaptation strategies to climate variability.

## Methodology

### Study Area

The study is carried out in Wayanad district of Kerala. Wayanad is one among the four major climate change hotspot districts in Kerala (KSACC 2014). Climate change hotspot analysis of Wayanad district shows that resilience of farmers to climate change is dismal due to number of socio-economic and geographical factors. Wayanad district is exposed to extreme climatic conditions such as drought and flood, particularly adverse effects of three consecutive flood since 2018 on biodiversity, livelihood, inhabitants' wellbeing of the area have been experienced. Moreover, Wayanad has higher concentration of tribal population with livelihood derived mostly from high climate sensitive agriculture and allied activities. The high geographical fragility along with irregular seasonal changes in climate makes farmers in Wayanad over the years resort to adaptation and coping strategies such as changes in cropping pattern, lift irrigation, mixed farming, use of early warning system, flood and drought resistant crop varieties, summer plaguing, inter change between direct sawing and transplantation, continuous cropping, early maturing verities, delayed sawing, diversification to non-farm activities, and conversion of farm area to tree crops in order to increase production of farm output.

### Data Collection

The study used cross section data collected from 138 paddy farmers in Panamaram community development block of Wayanad district. The samples for the study were selected on the basis of multistage random sampling. In first stage three blocks are identified according to the area under paddy cultivation and one community development block having largest area under paddy cultivation is selected. In the second stage, all5-gram panchayath in the Panamaram block is selected. In the third stage, 27 to 28 samples selected from each gram panchayath, as the sample units, which makes sums of 138 samples size for the study. Structured questionnaire is used for data collection, and data pertain to socio economic characteristics, various inputs costs incurred and outputs of paddy cultivations, formal and informal sources of credits to farmers, farmers perception to climate change, and finally adaptation and coping strategies employed by paddy farmers, among others were included in the questionnaire.

**Analytical Framework and Empirical Model**

The paddy cultivation in Kerala state faces long term challenges on account policy, technological and environmental fatigue (Jayan Jose T 2011).There has been persistent trend in decline of growth of area under cultivation, production and productivity in paddy cultivation ( Abraham MP 2019). Both price and non-price factors of which recently those associated with climatic variability may be identified as reasons for this dismal performance of paddy cultivation in Kerala. At present Kerala state has the shortage of around 84.46 percent of rice (M. Sujithra, 2014). There are large number of studies reported, deceleration in agricultural production started in mid 1970s. Its is against this background the present study attempts to unravel performance of paddy cultivation in terms of adaptation practices and coping strategies and its effects on technical efficiency.

**Analytical Tools**

One way in which performance of a production unit is usually analyzed by using the concept of efficiency[1]. Paddy farming as a production unit is said to be technically efficient[2] if it able to produce maximum possible output from the given set of inputs. Present study used technical efficiency to assess the performance of paddy cultivation in context of climatic change. The use of this methods has following advantages. Firstly, it is assumed in the study that paddy farmers adopt various coping strategies and adaptation practices are likely to be more efficient. Therefore, it is possible to measure factors of inefficiencies in paddy cultivation stems from variation in the coping strategies and adaptation practices adopted by the paddy farmers. Another advantage is that, such analyses bear policy implication for improvement of efficiencies by considering better adaptation option to climate change. In other words,

[1]Efficiency can be of two types. 1-Allocative efficiency: Allocative efficiency is defined as the ability and willingness to use the quantity of inputs that will maximize net revenue (profit), given the current conditions of factor supply and market demand. 2- Technical efficiency defined as the ability and willingness of farms to produce the maximum possible output with a specified quantity of inputs, given the prevailing technology and environmental conditions. In other words, a farm is said to be technically efficient, if it is able to realise the full potential of its technology with a given set of inputs.

[2]technical efficiency can further classify into input oriented technical efficacy and output oriented technical efficiency. Later is the ability of the production units to produce maximum possible output from given sets of inputs, where as former is the ability to produce a given level of output from minimum possible inputs costs.

suitable adaptation practices that contribute for the improvement in the efficiencies of paddy cultivation can be identified.

There are mainly non-parametric and parametric approach for measuring efficiencies of a production unit. Data Envelop Analysis(DEA) is a non-parametric approach where model estimation requires data of inputs and outputs only. It is deterministic in the sense that all deviation of output from maximum possible output attach to inefficiencies. Secondly, Stochastic Frontier Analysis (SFA) is a parametric approach where coefficients of independent input variable in the production function can be estimated. Moreover, SFA takes into account two types of random error which originate from usual stochastic as well as inefficiencies in nature. Present study adopts stochastic frontier specification of production as it best suits the objective of the study.

Specifying production function takes the form following (Batese & Coelli 1992) as in equation (1).

$$Y_i = \beta_0 + \beta X_i + \varepsilon_i \qquad (1)$$

Where,

$Y_i$ is the log of paddy output, $\beta_0$ and $\beta_i$ are parameters.

$X_i$ is the **Zx1** vector of input quantities, and $\beta$ is the **Zx1** vector of parameters to be estimated. $\varepsilon_i = -u_i + v_i$ assumed to be independently and identically distributed $N(0, \sigma_v^2)$ and independent of $u_i$, while $u_i$, are non-negative random variable, assumed to be independently and identically distributed as truncated-normal; $u_i \sim iidN^{+}(0, \sigma_0^2)$ distribution.

The equation (1) can be alternatively written as

$$Y_i = f(X_i; \beta) exp\,(u_i - v_i) \qquad (2)$$

Herer $f(.)$ can assume different functional formssuch as Cobb-Douglas and translog functional formsin present study production function assumes Cobb-Douglas type. From equation (2), technical efficiency of the paddy farmers can be defined as

$$TE_i = \frac{Y_i}{Y_i*} = \frac{f(X_i; \beta) exp\,(v_i - u_i)}{f(X_i; \beta) exp\, v_i} \qquad (3)$$

In equation (3), numerator is the actual observed output, and denominator is potential frontier output determined by the best production practices. Therefore

$$TE_i = exp\,(u_i) \qquad (4)$$

After the estimation of technical efficiency scores of individual paddy farmers, the next steps is to understand the effects of socio economic features of the farmers, coping strategies and adaptation practices of the paddy farmers on the technical efficiency. The technical inefficiency model can be specified in (5)

$$U_i = \delta_0 + \sum_{n=1}^{k} \delta_i Z_j \quad (5)$$

Where $U_i$ =inefficiency effects. $\delta_i$= coefficients of climate change adaptation practices, coping strategies and socio-economic factors and $Z_j$ is the vector of factors influences technical inefficiencies. Method of Maximum Likelihood followed by Battese & Coelli (1995) is adopted to obtain estimates of both stochastic frontier and inefficiency model in one step.

**Empirical Model**

Empirically the estimation of output, input variables and coefficients can be specified as following

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 \quad \textbf{(6)}$$

***Y*** = Total quantity of Paddy output(kg), explanatory variables $X_1$ **to** $X_6$measure inputs such as area under paddy cultivation (acres), human labour in man days, seeds(kg), organic manure(kg) and chemical fertilizer(kg), pesticides (liters), and $\beta_1$ *to* $\beta_6$measures their respective parameters.Empirical model for the technical efficiency/ inefficiency effects of farm specific socio-economic features, adaptation practices and coping strategies can be given as

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6$$

Where$\delta_1$to$\delta_4$indicatefarm specific socio-economic characteristics which influences the efficiencies such as years of education attainment of the farmer, size of the farm households, age of the farmer, year of farm experience. The expected relationship between education and technical inefficiencies is negative, because more years of education attainment helps farmers more accesses to up to date information to cope and adapt with changing climate, in turn decreases inefficiencies. Expected relationship between size of the farm household and inefficiency of the farms is positive, since increases in likelihood of a greater number of household participation in farming practices increases routinized and hard menial labour in farming and depresses efficiency of the farm. Relationship between experiences and technical inefficiency of the farmer is also expected to be negative because technical inefficiency of farm get reduces when the farmer gains more years of experience. In case of age, older the farmer become, lesser and lesser capable of carrying out daily farm operations, therefore expected relationship with technical inefficiency is negative.

Adaptation and coping strategies adopted by farmer to climate variability is included in the model as a factor that affects technical efficiency of paddy cultivation. At a time, farmer may use either few or large number practices to adjust with climate variability, hence they are complementary in nature rather than substitutable. Therefore, in the present study, parameters $\delta_5$to$\delta_6$ showscomplimentary coping strategies and complementary adaptation practices respectively. Important coping strategies used by the paddy farmers include adoption of drought tolerant/resistant seeds varieties, application of dip irrigation method, summer plaguing, interchange between direct sowing and transplanting, continuous cropping, crop insurance, shifting between early maturing and long maturing verities, delayed sowing, increase irrigation facilities.

Change in cropping patten, application of lift irrigation method, mixed farming, altering cropping pattern towards growing less water- intensive or rained crops, construction of farm ponds, livelihood diversification through increase in non-farm employment, increase in number of livestock particularly milch animals and goats, installation of new bore wells and wells, shifting from crops to trees crop, and migration are the important variable of adaptation. Since adaptation and coping strategies are complementary in nature, more and more practices jointly used by the farmer helps better to cope and adapt with climate variability, therefore, relationship between mean adaptation and coping strategy scores with technical inefficiency is expected to be negative.

**Result and Discussion**

Result in table-1 gives the distribution of paddy farmers according to the relevant socio-economic characteristics. The result shows that, more than 60 per cent farmers are older aged whereas only 38 percent farmers are found belonged to younger age. Very young generation paddy farmers are found very less in Panamaram where growing aversion of them towards paddy farming in particular will have implication for the sustainability of paddy cultivation in the next generation. Paddy production in Panamaram is dominated by the male since there are 85 percent paddy farm households are headed by male. Size of the paddy farm household in Panamaram is increasingly extended type, where 64.5

| **Table-1 Distribution of Paddy Farmers According to the Socio-Economic Characteristics** | | | **Variable** | **No of Famers** | **Percentage** |
|---|---|---|---|---|---|
| **Variable** | **No of Famers** | **Percentage** | **level of education** | | |
| | | | illiterate | 3 | 2.2 |
| **Age** | | | Primary | 13 | 9.4 |
| 20-35 | 4 | 2.9 | Secondary | 106 | 76.8 |
| 35-50 | 50 | 36.2 | Higher Secondary | 11 | 8 |
| 50-65 | 58 | 42 | Higher Education | 5 | 3.6 |
| 65-80 | 26 | 18.8 | **Farm Size** | | |
| **Sex** | | | Small & Marginal | 27 | 19.6 |
| Male | 118 | 85.5 | Medium | 83 | 60.1 |
| Female | 20 | 14.5 | Large | 28 | 20.3 |
| **Size of the Farm Households** | | | **Farm Experience** | | |
| ≤2 | 19 | 13.8 | ≤20 | 31 | 22.5 |
| between 3-5 | 89 | 64.5 | 20-40 | 70 | 50.7 |
| ≥6 | 30 | 21.7 | 40-60 | 31 | 22.5 |
| | | | 60-80 | 6 | 4.3 |

Source: Primary Data. September-October, 2019

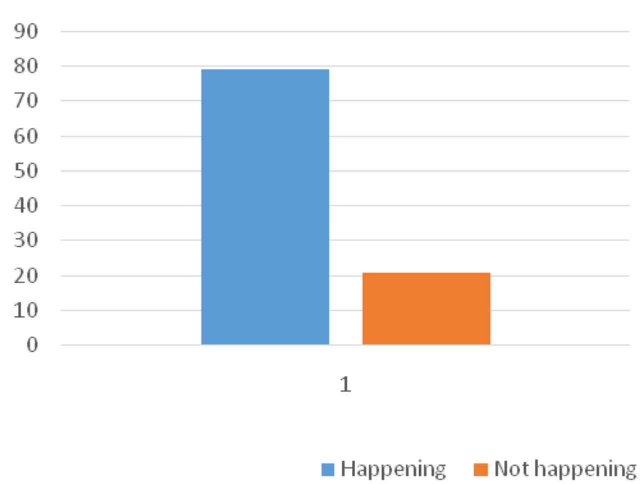
percent paddy farmers have the size of the households between 3-5 members per households. Typical joint family set up suitable for laborious paddy cultivation is fast destroying from the study area. Level of education among paddy farmers in Panamaram shows that there are 9.4 percent illiterate farmers, whereas majority of them completed secondary education.

The study adopted different way of classification of size of the landholding. Since the study had limited coverage of arear under paddy cultivation, study classified farmers landholding size based on acers. The result shows that 19.6 percent paddy farm operated with less than 1 acers of land and 20.3 percent operated on more than 4 acers of land. Majority of the paddy farmers in Panamaram are medium sized(1 - 4 acers) where 60.1 percent of them are operated in between 1 to 5 acers of land. Average size of the holding among Panamaram paddy farmers is 2.2 acers (0.89 ha). Analysis of the paddy farmers experience shows that 50 percent of the paddy farmers has 20-40 years of farm experience whereas more experienced farmers (more than 60 years)and less experience farmers (less than 20 years) are relatively less.

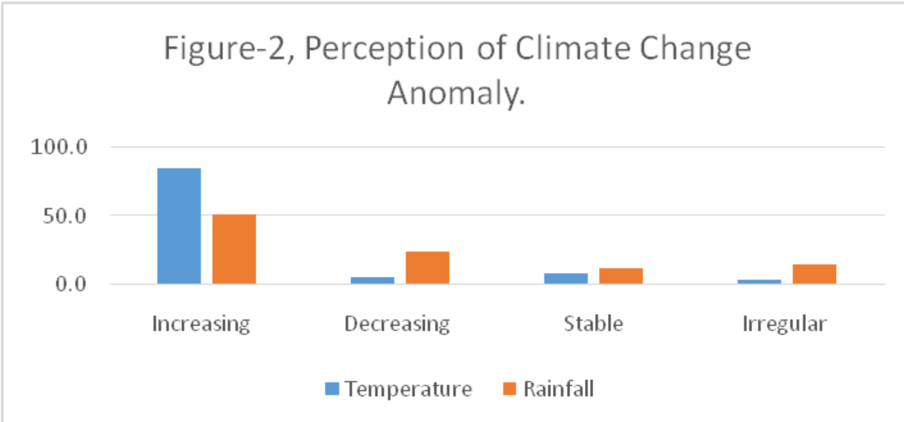
**Perception on Climate Change**

It is necessary to have an understanding about the perception of the paddy farmers about ongoing climate change before carryout any analysis of effects of climate change induced decision by them. Therefore, an attempt is made to analyze paddy farmers perception about the climate change from different dimension. When farmers are asked about their agreement on existence of ongoing climate change, 70.1 farmers agreed that climate change is happening. Whereas around 20.9percent paddy farmers not agreed on whether climate change is happening.When asked about the awareness climate change while majority of farmers could relate with flood, drought, excess rain, weed attack, delay in rainfall. However very few gives inappropriate perception about climate change by their description with ozone layer depletion and even to doomsday!

Figure-1, Agreement on Climate Channge.




To understand perception on climate change by farmers from different dimension, farmers have been given two climate change stimuli, such as temperature and rainfall. Farmers were then asked to give their opinion about changes in the temperature and rainfall from its long-term average. For example, in case of temperature, how far farmer perceived changes in long term average temperature from present level. Whether increasing, decreasing, stable/normal and irregular as




such. It is found that, 117 out of 138 farmers perceived (84.8 percent) an increase in temperature from long term average. Very few perceived changes in the temperature pattern in terms of decreasing, stable or irregular. In case of changes in the rain fall pattern, out of 138 sample, 70 farmers have perceived (50.7 percent) an increasing nature of present rainfall from long term average, 32 perceived (23.2 percent) decreasing nature of present rainfall from long term average, 16 perceived (11.6 percent) normal rainfall pattern and 20 perceived (14.5 percent) irregular nature of changes in ongoing rainfall pattern from the normal rainfall.

To understand most important climate change factor perceived by the paddy farmers, Garrett ranking techniques is used. In the present farm level study, farmers were asked to rank a number of alternatives from the following list regarding climate change factors.

- Temperature Changes
- Excess Rain
- Incidents of droughts
- Incidence of Flood
- Decline in Rainfall
- Delay in rainfall
- Growing Season Changes
- Extreme Weather events
- Forest Fire
- Land Slide

In Garret ranking technique, the paddy farmers ranking are first converted into score values with the following formula

Percent position = $100(R_{ij}-0.5)/N_j$

Where,

$R_{ij}$ = Rank given for the $i^{th}$ factor by the $j^{th}$ respondant.

$N_j$= No of factors ranked by the by the $j^{th}$ respondant.

The percent position is converted into scores by referring to Garret table after listing the frequency of the factor ranking. Then for each factor, the scores of each individual are added from which average scores are obtained. The selection of important factors of climate change according to Garrett ranking method is given in the table-2. From this table is clear that higher average temperature, incident of draught and excess rainfall are the three important climate events which dominate in the climate change perception of paddy farmers Incidents of flood, decline and delay in rainfall, growing season change are also found other important climate change factor perceived by the paddy farmers. Forest fire and land slide are least perceived climate change events

**Table:3 Dominant Factors in Climate Change Perception**

| Climate Change Factors | Garret Mean Score | Rank |
|---|---|---|
| Incidents of droughts | 58.4 | 1 |
| Higher average Temperature | 55.1 | 2 |
| Excess Rain | 54.6 | 3 |
| Incidence of Flood | 54.0 | 4 |
| Decline in Rainfall | 50.0 | 5 |
| Growing Season Changes | 42.6 | 6 |
| Extreme Weather events | 41.3 | 7 |
| Delay in Rainfall | 26.0 | 8 |
| Forest Fire | 10.0 | 9 |
| Land Slide | 0.02 | 10 |

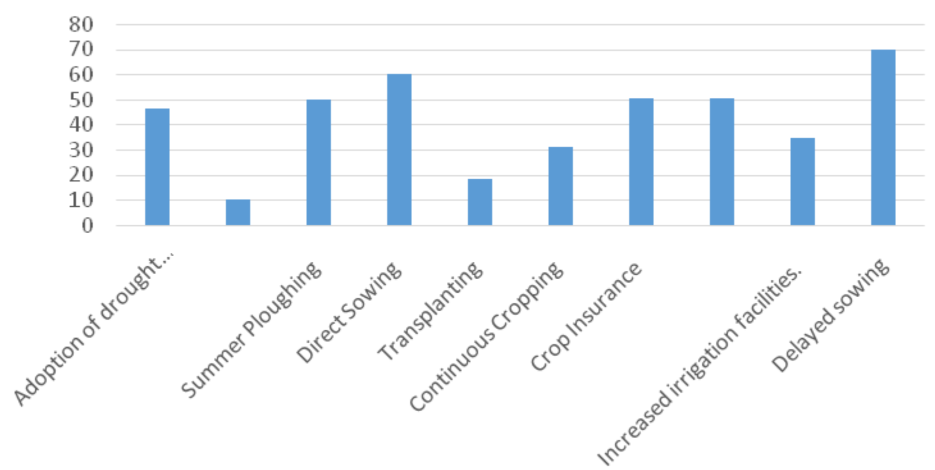
Source: Primary Data. Authors Calculation

**Adaptation Practices and Coping Strategies to Climate Change**

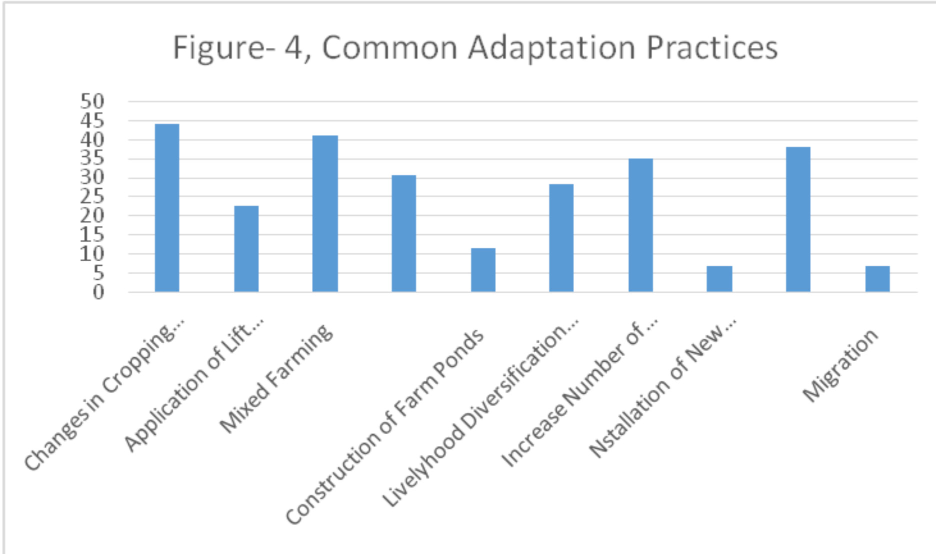
Adaptation to climate change means adjustment to actual or expected climatic stimuli to reduce risk and utilizing benefits of opportunities arises from adoption of such actions and for a long-term end in view. Whereas coping strategies are employed for reducing risks on account of climatic variability mainly for short term end in view. There are various literature attempt to assess effects of adaptation practices on efficiency of farming. Many of them considered adaptation and coping strategies under single broad adaptation practices, however did not distinguish adaptation practices and coping strategies specifically. Considering the time frame in which adjustment practices to climate change are adopted, an attempt is made to distinguish adaptation practices and coping strategies before analyzing their separate effects on the efficiency of paddy cultivation the study area.

The figure 3 describes commonly used coping strategies adopted by the Panamaram paddy farmers. It has been found that, making delay in sowing is the most commonly used coping strategies. Many paddy farmers (69.6percent) have to adopt delay in sowing and direct sowing (60.1 percent) due to late arrival of monsoon. Use of delay in sowing as a coping strategy is in accordance with the climate change perception of the paddy farmers in Panamaram. Moreover, half of the farmers adopted to direct sowing, crop insurance, and shifting from long to short maturing verities. Application of dip irrigation (10.1 percent) method is least adopted coping strategies in Panamaram.

Figure-3, Common Coping Strategies.




In general adoption rate among alternative adaptation practices is less frequent. No adaptation practices have been used by more than 50 percent paddy farmers. Changes in cropping pattern (43.8 percent), mixed cropping (41.1 percent), shifting from crops to tree crops (38 percent)are thecommon adaptation practices adopted by farmers. Since Wayanad agriculture generally follow homestead based cropping pattern, changing cropping pattern suitable for mixed farming and shifting from crop to tree crops may be appropriate adaptation practices for the many farmers. Farm diversification in the form of increase number of livestock particularly milch animals are practiced by only 34.9 percent paddy farmers, although adoption of this adaptation practices has complementary benefits within the farms. Along with milk and rice output production, exchange of by-product of grass straw and cow dung manure between farms fields become less possible when adoption of number on livestock rearing and milch animals in the farm households decreases. Practices like construction of farm ponds, installation of wells and borewell are adopted by a smaller number of paddy farmers. Migration is the least adopted adaptation practices.




**Complementary Adaptation and Coping Strategies**

Complementarity in adaptation practices and coping strategies is incorporated in the model to understand their separate effects on technical efficiency of paddy cultivation in Panamaram. In context of climate change and variability, farmers at a time need to adapt and cope with a greater number of strategies and practices. Since adaptation practices and coping strategies are not substitutable, complementarity in adaptation practices and coping strategies is likely to increases the efficiency of paddy production. In other words, complementarity in practices and strategies means ability of the farmers to undertake more than one strategy and practices to adjust with climate change and variability. The result of the complementary adaptation practices by paddy farmers shows that, majority adopted 3 to 7 number of adaptation practices. There are only 7 farmers adopted at least 8 number of adaptation practices and there are 7 farmers adopted only 2 number of adaptation practices. In case of complementary coping strategies, majority of the farmers adopted 4 to 8 number of coping strategies and however, no farmers adopted all coping strategies at a time in their farm. Minimum number of two coping strategies adopted by the one farmer and 5 farmers adopted maximum of 9 number of coping strategies.

Inability of the farmers to adopt a greater number of practices in their farms is determined by number of factors. Institutional supports to agriculture may be an important factor. For instance, although most of paddy farmers has coverage by the Cabini river, however, failure to provide canal irrigation facilities by public authority constraints farmers to implement other adaptation practices in the form of lift irrigation, construction of farm ponds.

**Table-3 Complementarity in Adaptation and Coping Strategies to Climate Change.**

| Number Of Practices/Strategies Adopted | Adaptation Practices | | Coping Strategies | |
|---|---|---|---|---|
| | No of farmers | Percentage | No of farmers | Percentage |
| 10 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0.7 | 5 | 2.6 |
| 8 | 7 | 5.1 | 31 | 16.1 |
| 7 | 18 | 13 | 39 | 20.3 |
| 6 | 27 | 19.6 | 43 | 22.4 |
| 5 | 32 | 23.2 | 49 | 25.5 |
| 4 | 33 | 23.9 | 21 | 10.9 |
| 3 | 13 | 9.4 | 3 | 1.6 |
| 2 | 7 | 5.1 | 1 | 0.5 |
| 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 |

Source: Primary data.

**Determinant of Technical Efficiency of Paddy Cultivation in Panamaram**

Table 1 present summary of output, inputs, farm spesific socio-economic characteristics of the samples for the study area. Result shows that, typical paddy farm households in Panamaram, on average cultivates 2.2 acers, and produce an verage of 4194.5 k.g of paddy outoput using only Nanja[3] season in a year. Most of the frmers practices cultivation on their unirrigated and rainfed paddy fields. On an average, paddy farmers use 72.5 k.g of seeds, 71 man days of labour, 1575.5 k.g of organic fertlizer, 243 k.g of inorganic fertilizer, 18.2 hours of machine labour and 0.9 liters of plant protection chemicals. The average values for the varibles in the efficiency model shows that on an average, paddy farmers attained 9 years of education, 55 years of age, 33 years of experiences. The average size of the housegolds among panamaram paddy farms is 4 members per family. Average values for complementary adaptation practices and coping strategies is 5 and 6 respectively.

**Table-4 Summar Statistics of Varible for the Model**

[3] Kerala follows three rice seasons. Wayanad has two; farmers refer to them as 'Nanja' (winter season,) and 'Punja' (summer season). (Aleena Thomas, 2020)

| **Production Model** | | | | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Min** | **Max** |
| Paddy Output(kg) | 4194.5 | 5719.6 | 500.0 | 55660.0 |
| Area under paddy (Acer) | 2.2 | 2.7 | 0.3 | 25.3 |
| Seed (kg) | 72.5 | 116.3 | 6.0 | 1163.0 |
| Total human labour(Man days) | 71.0 | 59.8 | 7.5 | 379.5 |
| Organic Fertilizer(kg) | 1575.5 | 1689.8 | 0.0 | 10000.0 |
| Inorganic Fertilizer(kg) | 243.0 | 318.6 | 0.0 | 2530.0 |
| Total Machine Labour(Hours) | 18.2 | 24.1 | 2.8 | 227.7 |
| Plant Protection(liters) | 0.9 | 2.4 | 0.0 | 25.0 |
| **Efficiency Model** | | | | |
| | Mean | SD | Min | Max |
| Education(years) | 9.1 | 2.9 | 1.0 | 17.0 |
| Household Size | 4.5 | 1.8 | 1.0 | 11.0 |
| Age (years) | 55.1 | 10.8 | 22.0 | 80.0 |
| Experience (years) | 32.6 | 15.0 | 1.0 | 70.0 |
| Complementary Adaptation practices | 5.1 | 1.5 | 2.0 | 9.0 |
| Complementary Coping Strategies | 5.8 | 1.5 | 2.0 | 9.0 |

Source: Primary Data, Authors calculation.

The influence of climate change adaptation and coping strategies in addition to farm specific other factors on the technical efficiency of paddy cultivation is analyzed. The Cobb-Douglas stochastic frontier model with inefficiency effect is selected as the preferred model that best fit the data for the paddy farmers. Maximum likelihood estimates for the production as well as efficiency model for stochastic frontier analysis is presented in table-5. Estimate on return to scale shows 0.93 indicates decreasing return to scale operate in the paddy cultivation in Panamaram.Estimated parameters are highly significant effect on paddy production except for machine labour and plant protection.

The efficiency model shows that inefficiency effects exist in the model because γ = 1 (γ is called gamma ratio explain variation in frontier output on account of farm specific factors and adaptation practices as well as coping strategies adopted by the paddy farmers, if technical inefficiency present in the model, γ ration will be lies between great than zero and less than one.) Estimated coefficient for education, age and adaptation practices is negative and highly significant. More and more years of education level by paddy farmers helping them to better manage farm operation with greater awareness in better quality of inputs, in turn decreases the inefficiency. Estimated parameters for age is negative and significant implies that higher ages of the farmers increase the skills in doing various farm operation over the years and thus decreases technical inefficiency. Estimated parameters for the complementary adaptation practices is also negative and significant implies, greater the combination of alternative adaptation practices adopted on per farms, better the farms to adjust with climate changes and decreases the inefficiency in paddy production.

**Table-5: Maximum Likelihood Estimates for Stochastic Frontier Analysis**

| **Production Model** | | | **Efficiency model** | | | **Diagnostic Parameters** | | |
|---|---|---|---|---|---|---|---|---|
| Variables | Coefficients | P>IzI | Education Level | -0.09002 | 0 | Mean technical inefficiency | -0.1645 | 0.002 |
| Farm Size | 0.91202 | 0 | Household Size | 0.009297 | 0 | Insigma2 | -2.31 | 0 |
| Labour (Man days) | 0.1484 | 0 | Age | -0.4467 | 0 | Igtgama | 29.3 | 0.801 |
| Seeds (KG) | 0.03002 | 0 | Experience | 0.054863 | 0 | Sigma2 | 0.098727 | |
| Manure (K.G) | 0.0306 | 0 | Adaptation Practices | -0.008 | 0 | gamma | 1 | |
| Machine Labour (Hours) | -0.195 | 0 | Coping Strategy | 0.32 | 0 | Sigma_u2 | 0.0987 | |
| Plant Protection (Litters) | -0.001 | 0 | | | | Sigma_v2 | 1.69E-14 | |
| Return to scale | 0.92504 | | | | | | | |

Estimated parameters for household size, experience and coping strategies is positive implies an increase in any of this factor increases the technical inefficiency. As the size of the households get increases, expectation about the future fragmentation in land holding perhaps affecting present operation in paddy cultivation thereby decreasing the efficiency of farm operation in the Wayanad study area. Contrary to the expected relationship between experience and technical inefficiency, present study found positive and significant relationship in Wayanad study area. Complementary adaptation strategies by paddy farmers adopt in their farm may not be a suitable mix of strategies perhaps increased the inefficiency. Adoption of adaptation practices as compared to coping strategies is relatively more effective on influencing the technical efficiency of paddy cultivation in addition to the other farm specific socio-economic factors.

**Conclusion**

With the objective to carry out study to understand the effects of adaptation practices and coping strategies in paddy cultivation on efficiency of paddy cultivation, present research incorporated separate effects of technical efficiency of adaptation practices and coping strategies. Separate treatment of the adaptation practices and coping strategies in technical efficiency analysis is first attempt in this field of research. Prior to the analysis of effects of climate change adjustment practices on efficiency of the paddy cultivation in the study area, present study attempted to understand climate change perception of the paddy farmers from different dimensions. When majority of the paddy farmers agreed on the existence of ongoing climate change with increase in long term average temperature, incidents of droughts and flood, excess rain, decline and delay in the arrival of rainfall are the climate change factors dominate in the paddy farmers perception. Making delay in sowing is the common coping strategies adopted by the Panamaram paddy farmers. Changes in cropping pattern is the common adaptation practices to climate change by the paddy farmers by Panamaram paddy farmers. When only 23 percent paddy farmers found 4 complementary adaptation practices whereas 25 percent paddy farmers adopt 5 complementary coping strategies. Adaptation of particular adaptation practices is depending on the kind of supplementary support services by the public authority. The efficiency effects of adaptation strategies are more effective in improving the efficiency of paddy cultivation in Panamaram paddy farmers. Therefore, it is imperative the adaptation and coping strategies in the farm level planning in context of climate change.

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