__Original Research Article__

Adaptation strategies of farming communities against climate induced changes in Chilika lake wetland ecosystem of Odisha

ABSTRACT

Chilika, a brackish water coastal lagoon situated in Odisha, forms the base of livelihood security for more than 0.2 million fishers and 0.4 million farmers living in and around the wetland and its adjoining catchments. The aim of the study is to identify various adaptation strategies of farming communities under climate-induced changes in the wetland and to estimate the parameters involved in determining the strategies. The study has been conducted in Chilika lake including the peripherals districts Khurda, Puri and Ganjam of Odisha. Primary data of 120 farmers across different sectors and secondary data pertaining to natural calamities occurred in the area has been used for the analysis. The statistical tool probit analysis was used to estimate the parameters and its marginal effects on different adaptation strategy has identified. The various stakeholders had different adaptation strategies against climate change. In the case of the farming community water conservation methods, Integrated farming system, institutional aids, agronomic measures and cultivation of climate resilient varieties were the major adaptation strategies. It is found that 62.5 per cent of the farmers were going for climate resilient varieties, especially salt, drought and pest tolerant varieties. About half of the farmers were adopting agronomic measures to cope with climate change. Almost 60 per cent were depending upon institutional aids for various adaptation practices as well as gathering information for preparedness against any natural calamity. Less than half of the farmers responded that they were practicing integrated farming system and using water saving techniques against uncertainties in the weather. The results of the probit model revealed that age, education, landholding, income from wetlands, Income from other sources and level of awareness were found to have a significant role in going for various adaptation strategies.

Keywords: Climate change, adaptation, probit model, Chilika, farming

1. INTRODUCTION

Climate regulation is one of the most significant ecosystem services provided by wetlands, and also it has immense role in buffering the effects of climate change and thereby supporting climate adaptation and resiliency as well as many additional ecosystem services. Millennium Ecosystem Assessment (2005) [1]. Wetlands are valuable and ecologically sensitive systems that occupy about 6% of the world's land surface (Turner et al.,2000) [2]. Wetlands play an important role in flood control. Wetlands help to lessen the impacts of flooding by absorbing water and reducing the speed at which flood water flows. In view of their effectiveness associated with flood damage avoidance, wetlands are considered to be a natural capital substitute for conventional flood control investments such as dykes,dams, and embankments (Boyd and Banzhaf, 2007) [3]. Lake Chilika, the largest coastal lagoon on the east coast of India and lifeline of the state of Odisha, is a designated Wetland of International Importance (Ramsar Site under the Convention on Wetlands) [4] Chilika Lake, with its rich biodiversity and scenic beauty, is one of the important tourist destinations of the state, and accounts for 8-10% of the total tourist arrival into the state. Chilika is one of only two lagoons in the world that supports Irrawaddy Dolphin (*Orcaella brevirostris*) populations. Barkudia insularis, a limbless skink, is endemic to Chilika. Lake Chilika, with an enormous storage capacity of 1200 Million cubic mteters (MCM) of water (with a water level variation in excess of a meter) provides a huge capacity for buffering floods and impacts of extreme events.

Climate change (CC) is likely to intensify coastal hazards imposing significant challenges on coastal regions (Adger et al., 2005). [5] Odisha is the state which is very prone to natural calamities such as flood and cyclones. Quantitative estimations regarding the impact of climate change on wetlands are scarce in the literature, especially in developing countries where the primary data both on physical impacts and valuation are limited and difficult to obtain (Mehvar et al., 2018b) [6] . The potential consequence of any climate change- driven variation in wetlands would be particularly high in developing countries due to the inherently low adaptation capacity, and the high dependence of local communities towards wetlands. This main objective of the study is to identify various adaptation strategies for farming communities under climate-induced changes in the wetland and estimate the parameters involved in determining the strategies. This study is an attempt to identify different adaptation strategies by the farming communities against climate change happening in Chilika Lake catchment and its peripheral districts, which supports the formulation of various contingency plans for the area.

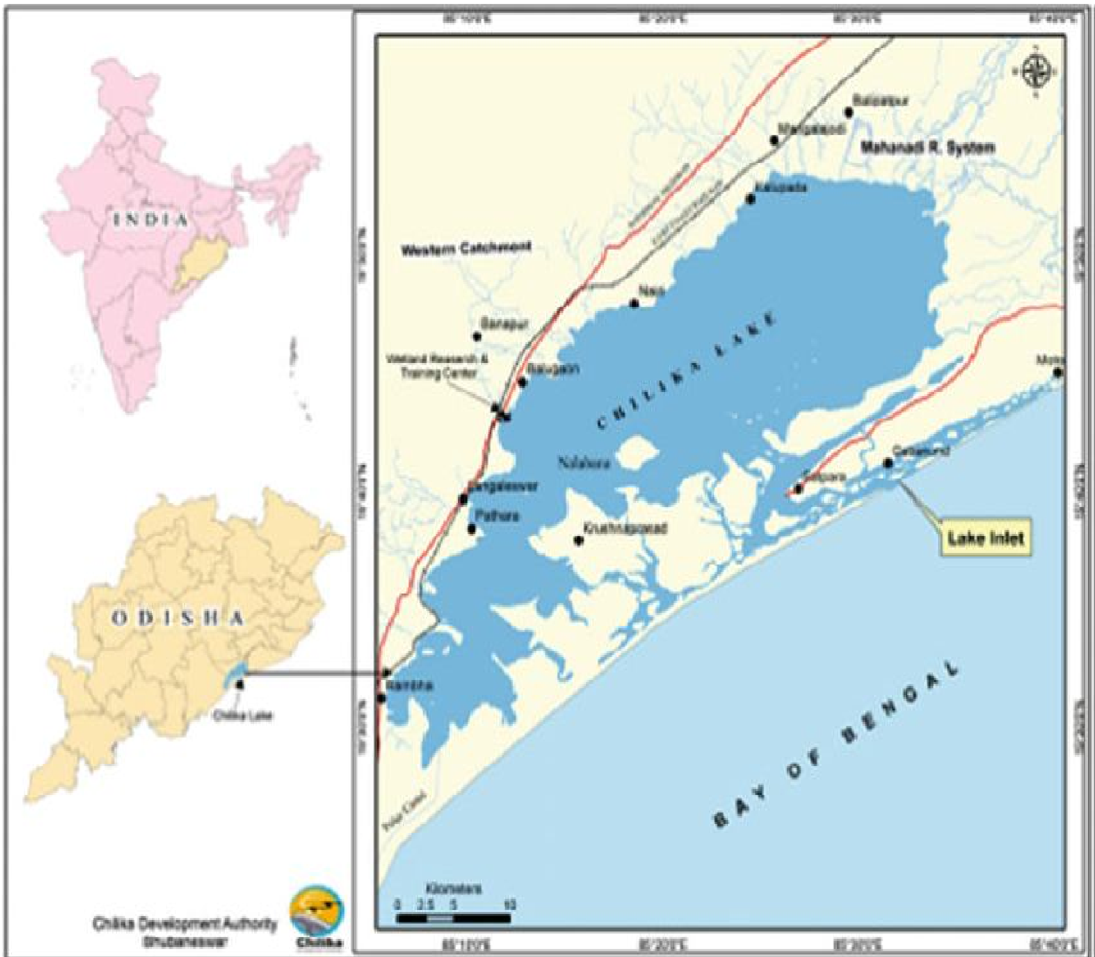
2. METHODOLOGY

2.1 Study area

Chilika Lake (19°28‟N-19°54‟N and 85°6‟E-85°35‟E) lies in the districts of Puri, Khurda and Ganjam in the state of Orissa, on the eastern coast of India (Fig.1). Chilika lies on the main Madras-Calcutta highway (National Highway 5) and Madras-Howrah rail line passes the western bank, near Balugaon, Chilika and Rambha being the main stations along the Lake. Chilika lies about 50 km southwest of the city of Puri from where one can approach Satapara by road on the eastern bank of Chilika. It is 100 km away from Biju Pattnaik Airport, Bhubaneswar and 1 km from Balugaon railway station.

The Lake is surrounded by a strip of silted and reclaimed land. On the northeast margin lies an extensive area of marshy land, some of which has been reclaimed for agriculture. Other silted-up lands around the northern and central margins have been reclaimed for agriculture and are separated from the Lake by bunds (dykes). The Lake margins are steeper in the central and southern sectors and rocky promontories jut out into the Lake at several places. The land is less flat and somewhat rocky, being part of the Eastern Ghats. The estuary of the Rushikulya River lies about 18 km down the coast and is separated from Chilika by lowlands, some of which are used as salt pans (Rao *et al.* 1986).[7] The 21 km long Palur canal connects the Rushikulya estuary to the Lake.

UNDER PEER REVIEW



Source: Chilika Development Authority

Fig.1 Map of Chilika Lake

2.1.1 Climate and rainfall

Chilika‟s location on the coast in the tropical zone spares it from extreme temperatures. The rainfall over the area varies from 1007 - 1,146 mm, increasing towards the northeast having an annual average rainfall of 1202 mm. Source: (Chilika Development Authority, Report, 2001). Most of the rain (80 %) occurs during the South West monsoon season. The Lake area experiences mean wind speeds ranging from 0.678 to 86.10 kmph at Chnadraput and Satapada (CDA Report, 2001) [8]. However, the coastal areas experience higher wind speeds. Being on the Bay of Bengal, Chilika is also subjected to cyclonic activity during May – December. The Lake area experiences mainly three seasons, namely Summer (March-June), Rainy (July to October) and Winter (November to February). Two Automatic Weather Stations have been installed by CDA within the campus of the Visitor Centre, Satapada and Wetland Research & Training Centre (WRTC) at Chandraput to record various meteorological parameters (Air Temperature, Relative Humidity, Wind Speed & Direction, Solar Radiation, Rainfall) relating to the Lake area.

Rainfall in the region is contributed by southwest and northeast monsoons from June to September and November to December, respectively. About 75% of the annual rainfall is received during the monsoon months from June to September. Rainfall generally decreases from northeast to south-west. The monsoon starts by about the second week of June and withdraws early in October. Wind speed is higher from March to July and speed is low during the winter season.

2.1.2 Soil types

The broad soil groups in the Chilika catchment, as identified by the Directorate of Soil Conservation, Orissa in 1988 [9] include-

- Red Soils (Alfisols): These soils are developed on the plains and slightly undulating uplands in the northwestern regions. These are characterized by moist soils with B horizon of clay accumulation, horizons of grey, brown or red colour, surface horizon not darkened by humans and water available to plants for at least 3 consecutive months.

- Laterite Soils (Ultisols & Oxisols): Developed on the excessively drained and porous lateritic mass, these soils are found on the pediment zones and uplands. Oxisols represent those soils which are very old and highly weathered. The ultisols represent the soils developed in varied climates e.g. moist subtropical climate, wet-dry tropical climate and monsoon climate. These form under forest cover. B horizon of well drained ultisols looks red or yellowish brown. These contain accumulated clay.

- Black Soils (Vertisols) : These loamy to clayey textured soils are found in a singular patch south of Sunakhala village. The vertisols are characterized by the high content of clay that swells on hydration and shrinks on dehydration, wide deep cracks during the dry season and movement of soil during the wet season.

- Brown Forest Soils (Humults): These are rich in organic matter and found in the hilly tracts in the western and southwestern regions. Humults are suborders of Ultisols, which have high to a very high content of organic matter formed under high rainfall. D.2.4.5.12.4 Alluvial soils (Entisols) These are fertile soils found on the flood plains of Daya, Bhargavi and Makara River and river alluvium of small rivulets. Entisols are very poorly developed soils with no horizon.

- Coastal Saline and Sandy Soils (Haplaquents/ Ustipsamments): Coastal alluvial soils with high soluble salts and sandy soils of the coastal region come under this category. Aquents and Psamments are suborders of Entisols. Aquents are seasonally saturated with water and are generally gleyed. The Psamments are sandy or loamy sand textured soils.

2.1.3 Land use pattern

The landcover/ landuse map derived from satellite imagery indicates that the predominant land use class in the catchment area is agriculture characterized by 61.55% of the total catchment area. However, the western catchment under the Eastern Ghat domain is represented by a major patch of forest area characterized by mixed deciduous forest. The land cover of Chililka is depicted in Table 1 and (Fig. 2)

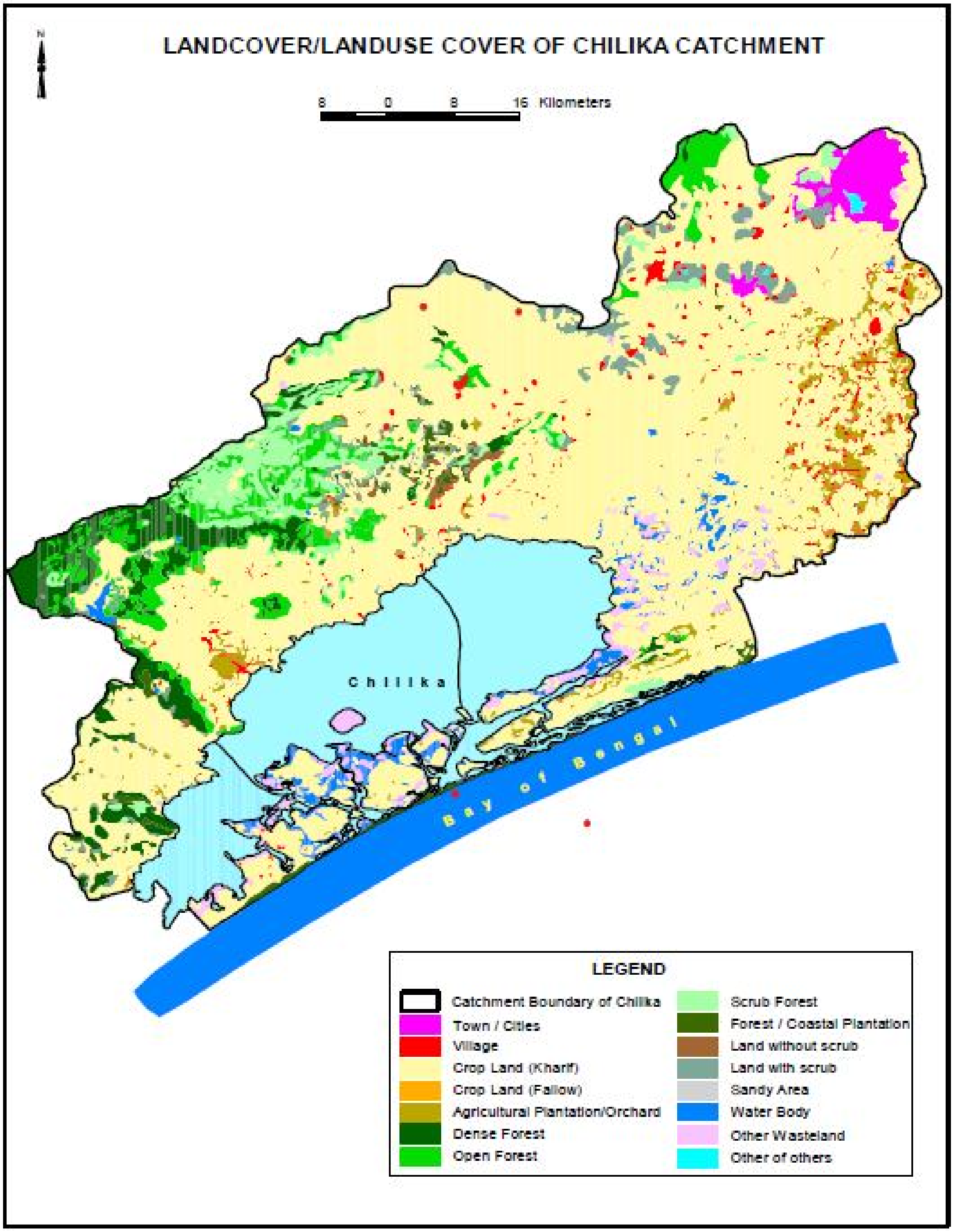
UNDER PEER REVIEW

Table 1. Land use pattern of Chilika Lake

Land cover/ Land use Class	Area in Sq. Km.	Percentage of Total Area
Town/Cities	83.80	2.10
Village	126.29	3.17
Dense forest	229.05	5.74
Open forest	257.64	6.46
Scrub Forest	176.91	4.44
Forest/coastal plantation	74.35	1.86
Land with scrub	141.43	3.55
Land without scrub	18.87	0.47
cropland (fallow)	0.31	0.01
crop land (Kharif)	2454.40	61.55
Agricultural plantation/Orchard	176.13	4.42
Sandy area (river/coastal)	0.01	0.00
Wasteland (Marshy/Swampy/Waterlogged)	108.14	2.71
Waterbody	136.90	3.43
Other	3.17	0.08
Total Catchment	3987.40	100.00

Source : Chilika Development Authority

UNDER PEER REVIEW



Source: Chilika Development Authority, Bhubaneswar

Fig.2 Land use coverage of Chilika Catchment

2.2 Nature and sources of data

Primary data was collected from the respondents living in the villages of different sectors of Chilika from districts of Puri, Ganjam and Khurda. Socio-economic data, cost of cultivation of paddy and adaptation strategies towards climate change were calculated from various stakeholders. A detailed household survey has been conducted between February 2020 and October 2021.

2.3 Analytical techniques

2.3.1 Probit regression

The probit regression model is employed to estimate the parameters that determine the adaptation strategies against climate change by the farmers of Chilika.

In this model the response variable Y is binary, that is it can have only two possible outcomes which we will denote as 1 and 0. For this study 'Y' represents whether the farmer has gone for a certain adaptation strategy or not. We also have a vector of regressors X, which are assumed to influence the outcome Y. Specifically, we assume that the model takes the form

$$\Pr(Y = 1 \mid X) = \Phi(X^T \beta),$$

Where Pr denotes probability and Φ is the Cumulative Distribution Function (CDF) of the standard normal distribution. The parameters β are typically estimated by maximum likelihood. The probit model with multiple repressors is as follows

$\Pr(Y = 1 | X_1, X_2) = \Phi(\beta_0 + \beta_1 X_1 + \beta_2 X_2)$

- Φ is the cumulative normal distribution function.

- $z = \beta_0 + \beta_1 X_1 + \beta_2 X_2$ is the " z-value" or " z-index" of the probit model.

- β_1 is the effect on the z-score of a unit change in X_1, holding constant X_2

The variable includes:

Y = Different adaptation strategies

X_1 = Age, X_2 = Education in years, X_3 = Landholding , X_4 = Income from wetlands,

X_5 = Level of awareness

The model used in the study was analyzed using the software STATA.

3. RESULTS AND DISCUSSION

3.1 Adaptation strategies of the farming community to the climate induced changes in the Chilika lake.

The Chilika lake as well as the coastal districts of Odisha are prone to various natural calamities. The various natural calamities that happened in Chilika lagoon along with the year of occurrence are given in Table 2. It is found that natural calamities floods and cyclones were more frequent when compared to drought and earthquakes. The major adaptation strategies identified from the response among the farmers of Chilika lake were

UNDER PEER REVIEW

the cultivation of climate resilient varieties, practising an integrated farming system, adopting agronomic measures, following institutional aids and usage of water saving techniques.

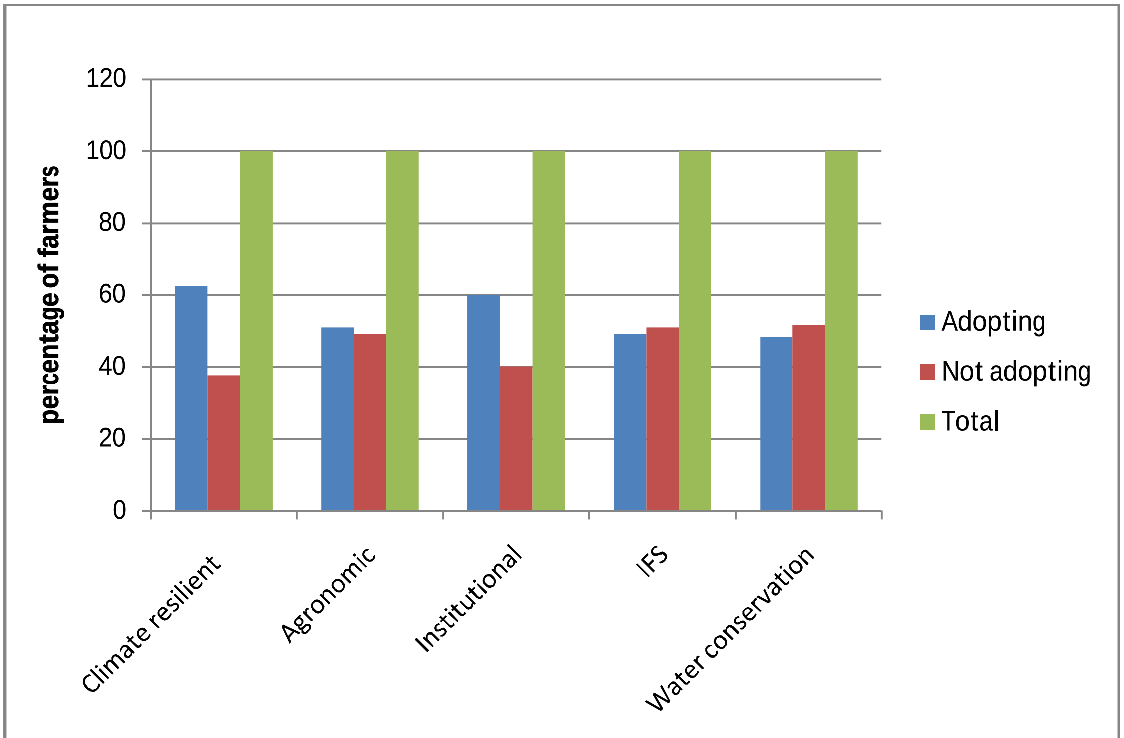
Table 2. List of natural calamities in Chilika Lagoon

Category	**Year of occurrence**
Cyclone	1967, 1968, 1970, 1971, 1972, 1973, 1999, 2013, 2014, 2019
Drought	1956, 1970, 1987, 2000, 2002, 2010, 2015
Earthquake	2013, 2015
Flood	1956, 1959, 1969, 1970, 1986, 1987, 1988, 1990, 1991, 1992, 1993, 1994,
	1995, 1996, 1997, 1998, 1999, 2001, 2003, 2005, 2006, 2008, 2011, 2014

Source: Modified from Sundaravadivelu *et al*.. (2019) [10]

It is evident from (Fig 3) that about 62.5 per cent of the farmers were going for climate resilient varieties, especially salt, drought and pest tolerant varieties. About half of the farmers were adopting agronomic measures to cope with climate change. Almost 60 per cent were depending upon institutional aids for various adaptation practices as well as gathering information for preparedness against any natural calamity. Less than half of the farmers responded that they were practising integrated farming systems and using water saving techniques against uncertainties in the weather.

UNDER PEER REVIEW



Source: Author, 2023

Fig 3. Percentage of various adaptation strategies by farmers.

The results from probit analysis used to estimate the parameters involved in determining the adaptation strategies given in Table 3 reveals that the parameter age of the farmers has a significant positive marginal effect towards the strategies agronomic measures and institutional aids at one per cent level of significance, whereas it has a significant negative marginal effect for IFS and water saving methods. The parameter education has a significant positive effect on the strategies adapting climate resilient varieties, agronomic measures and institutional aids, meanwhile it has a significant influence on the strategy water saving methods. The land holding size of the farmer was found positively affect the strategies of IFS and water saving methods, but it was found negatively effecting both agronomic and institutional aids. The factor income from wetlands had a significant positive effect on all the strategies except the adaptation of climate resilient varieties. The level of awareness was found positively significant for climate resilient varieties and negatively significant for the strategies towards IFS and agronomic measures.

Table 3. Estimation of the parameters involved in determining the adaptation strategies

Independent Variable →	**Climate resilient varieties**	**Integrated Farming System**	**Agronomic measures**	**Institutional aids**	**Water saving methods**
Parameters ↓	**Marginal effects ($\frac{dy}{dx}$)**				
Age	-0.005 (0.312)	-0.010*** (0.002)	0.018*** (0.002)	0.018*** (0.000)	-0.136*** (0.001)
Education in Years	0.045*** (0.002)	-0.017 (0.121)	0.030** (0.121)	0.069*** (0.000)	-0.276** (0.035)
Landholding	-0.125 (0.261)	0.227*** (0.000)	-0.376*** (0.000)	-0.218** (0.011)	0.018 (0.885)
Income from wetlands	0.054 (0.486)	0.126*** (0.002)	0.219*** (0.002)	0.245*** (0.000)	0.267*** (0.009)
Level of awareness	0.017*** (0.000)	-0.001*** (0.001)	-0.014** (0.001)	-0.005 (0.912)	0.006 (0.882)
Constant	- 4.07** (0.034)	0.211 (0.833)	-0.477 (0.778)	-6.66*** (0.000)	1.52 (0.285)
LR chi^2	**65.88**	**74.33**	**31.05**	**55.89**	**53.99**
Prob> chi^2	**0.000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**
No of observations	**120**	**120**	**120**	**120**	**120**

Note: Figures given in the parenthesis are the p-value

Note: ***, **and *implies significanceat1%, 5% and 10% respectively

Source: Author, 2023

UNDER PEER REVIEW

The Chilika lake as well as the coastal districts of Odisha are prone to various natural calamities. The various natural calamities that happened in Chilika lagoon along with the year of occurrence were shown in Table 2. It is found that natural calamities floods and cyclones were more frequent when compared to drought and earthquakes. The major climate risks opined by the farmers of the study area were farmers were drought, flood, cyclone, crop disease and pest attack.

According to Matthews and Wassmann (2003) [11], adaptation is an adjustment made within the crop production systems, in order to live successfully in changing climate. The technological changes for adaptation with special reference to rice cultivation will aim at the introduction of tolerant cultivars and methods of cultivation for improved input efficiency. Smit and Skinner (2002) [12] have categorized farm-level adaptations into three main categories, i.e., changes in farm management practices, farm-level technological developments, and financial management for farm protection. Based on these broad categories, studies have identified several adaptation strategies. The major adaptation strategies identified and categorized as per the response among the farmers of Chilika lake were the cultivation of climate resilient varieties, practising an integrated farming system, adopting agronomic measures, attaining the support of institutional aids and usage of water-saving techniques.

The climate resilient varieties mainly cultivated in the area are Swarna sub -1 which is tolerant to flash flooding and Luna suvarna which is salt tolerant. The IFS practices include crop diversification, fishing, poultry and other enterprises to balance the loss from a single crop or enterprise. Rice–fish farming systems are adopted in some of the submergence-prone areas. Agronomic measures include strengthening the field bund height & check the seepage loss, specific nutrient management, changing the planting date and adjusting the cropping season. Krishnan *et al.* (2007) [13] demonstrated the potential outcomes by adjusting the sowing time of rice in two sites (Cuttack and Jorhat in India) by simulating the crop growth under different climate change scenarios. Crop insurance and early weather warning systems were the major institutional aids which need further deepening in the area. Additions of crop residues and manure to the soils improved the soil water holding capacities. Water harvesting structures were used to tap non-saline water to irrigate the crops after the monsoon and in-situ rainwater conservation was the main water conservation method.

The results from probit analysis were used to estimate the parameters involved in determining the adaptation strategies given in Table 3. The marginal effect in the analysis is the average change in the probability of going for a specific adaptation strategy when the selected parameter increases by one unit. The results revealed that the parameter age of the farmers has a significant positive marginal effect towards the strategies agronomic measures and institutional aids at one per cent level of significance, whereas it has a significant negative marginal effect for IFS and water saving methods. The parameter education has a significant positive effect on the strategies adapting climate resilient varieties, agronomic measures and institutional aids, meanwhile it has a significant influence on the strategy water saving methods. Farmers who attained higher education are more likely to adapt to climate change by switching to different adaptation strategies. Study findings are in line with Maddision's (2006),[14] Kibue *et al.* (2016) [15] and Singh (2020) [16]. The marginal effects in the land holding size of the farmer were found positively affect the strategies IFS and water saving methods, but it was found negatively effecting both agronomic and institutional aids. The factor income from wetlands had a significant positive effect on all the strategies except the adaptation of climate resilient varieties. The level of awareness index was found positively significant with respect to climate resilient varieties and negatively significant for the strategies towards IFS and agronomic measures. Similar

UNDER PEER REVIEW

studies were reported by Singh (2020) [16] among farmers in the dry region of Bundelkhand (Uttar Pradesh).

4. CONCLUSION

The major adaptation strategies identified from the response among the farmers of Chilika lake were the cultivation of climate resilient varieties, practising integrated farming systems, adopting agronomic measures, following institutional aids and usage of water saving techniques. It is found that 62.5 per cent of the farmers were going for climate resilient varieties, especially salt, drought and pest tolerant varieties. About half of the farmers were adopting agronomic measures to cope with climate change. Almost 60 per cent were depending upon institutional aids for various adaptation practices as well as gathering information for preparedness against any natural calamity. Less than half of the farmers responded that they were practising integrated farming systems and using water saving techniques against uncertainties in the weather. The results of the probit model revealed that age, education, landholding income from wetlands, Income from other sources and level of awareness were found to have a significant role in going for various adaptation strategies.

This study provides understanding of adaptation decisions adopted by sample farmer of Chilika. As a process of involving perceptions of climate change, farmers utilized their leanings from past experiences in dealing with climate change, risk and uncertainities. The results provide useful insights for necessary policy interventions. Climate resilient areas may be piloted in the Chilika with end-to-end support from agriculture technology transfer, infrastructure, inputs, implements and weather advisory services to develop understanding and confidence of the farmers to adapt to new technology and practices addressing climate change including non-farm activities like insurance and credit facilities. This particular study has taken socioeconomic characters of the sample farmers and the result will be valid only if these variables are taken into account.. This work also generates scopes for future research on other determinants of climate change adoption among farmers as well as among other stake holders of Chilika Lake.

UNDER PEER REVIEW

REFERENCES

1. Millennium Ecosystem Assessment., Ecosystems and human wellbeing:Wetlands and water synthesis. World Resources Institute, Washington, DC, 2005 ;p 1

2. Turner RK, van den Bergh JCM, Soderqvist T, Barendregt A, van der Straaten J, Maltby E, van Lerland EC. Ecological-Economic Analysis of Wetlands: Scientific Integration for Management and Policy, *Ecological Economics*, 2000; 35, pp. 7-23

3. Boyd, J., Banzhaf, S.,What are ecosystem services? The need for standardized environmental accounting units. *Ecol. Econ*. 2007. 63 (2–3), 616–626.

4. Ramsar Convention on Wetlands, Information sheet on wetalands Ramsar. [Briefing Note]. The Secretariat of the Convention on Wetlands, Gland, Switzerland. 1992 December.

5. Adger WN, Hughes TP, Folke C, Carpenter SR, Rockström J. *Social-ecological resilience to coastal disasters*. Science 309 (5737), 2005; 1036–1039.

6. Mehvar S, Filatova T, Dastgheib A, de Ruyter van Steveninck E, Ranasinghe R.. Quantifying economic value of coastal ecosystem services: a review. J. Mar. Sci. Eng. 2018a: 6 (1), 5.

7. Rao DP, Subramanian SK, Sudarsana R; Geomorphic analysis of Chilika Lake and adjoining area using remotely sensed data, Photonirvachak. *J Indian Soc Remote Sens.* 1986.,14:53–60

8. CDA Report on Chilika: environmental monitoring,. Chilika Development Authority, Bhubaneswar. 2001; vol 103.

9. Mishra, D.P. Tech. Bull. Directorate of Soil Conservation, Orissa. 1988,

10. Sundaravadivelu, R., Shanmugam, P., Patnaik, A. K., & Suresh, P. K., Migration of Chilika Lake Mouth. In *Proceedings of the Fourth International Conference in Ocean Engineering (ICOE2018);* 2019 (pp. 369-380). Springer, Singapore.

11. Matthews, R. B., and Wassmann, R... Modelling the impacts of climate change and methane emission reductions on rice production: A review. *Eur. J. Agron*. 2003; 19, 573–598.

12. Smit, B.Mark, Skinner, W.,Adaptation options in agriculture to climate change: a typology. Miti. Adap. Strat. Glob. Chan. 2002 ; 7 (1), 85–114.

13. Krishnan, P., Swain, D. K., Bhaskar, B. C., Nayak, S. K., and Dash, R. N.. Impact of elevated CO2 and temperature on rice yield and methods of adaptation as evaluated by crop simulation studies. *Agric. Ecosyst. Environ.* 2007., 122, 233–242.

14. Maddison, D.. The Perception of and Adaptation to Climate Change in Africa. CEEPA. Discussion paper No. 10, Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria. 2006

15. Kibue, G.W., Liu, X., Zheng, J., Zhang, X., Pan, G., Li, L., Han, X.,. Farmers' perceptions of climate variability and factors influencing adaptation: evidence from Anhui and Jiangsu. Chin. En. Man. 2016., 57 (5), 976–986.

16. Singh, S.; Farmers' perception of climate change and adaptation decisions: A micro-level evidence from Bundelkhand Region, India. *Ecological Indicators*, 2020., *116*, 106475.

UNDER PEER REVIEW