Irrigate or Not to Irrigate? - Do Risk Factors Influence Coconut Farmers' Irrigation Decisions? Evidence from Kerala, India

by M. Anoop, Smita Sirohi, and H.P. Singh

ICAE 2021
INTERNATIONAL CONFERENCE
OF AGRICULTURAL ECONOMISTS
AUGUST 17-31, 2021 - ONLINE

Irrigate or not to irrigate ? – Do risk factors influence coconut farmers' irrigation decisions ? Evidence from Kerala, India

M. Anoop[1], Smita Sirohi[2] and H.P. Singh[1]

1: Department of Agricultural Economics, Banaras Hindu University, India,
2: Division of Dairy Economics, Statistics and Management, ICAR-National Dairy Research Institute, India

Abstract

Low productivity of coconut palms is a major issue faced by farmers in Kerala. By providing adequate irrigation and other better management practices this can be solved in a significant way. Even then, many farmers are not adopting irrigation and thus not able to get adequate returns from the farm. Risk is one of the important factors affecting farmers' adoption decision of new technologies and better management practices. Present paper tried to study the effect of risk on adoption of irrigation by the coconut farmers of Kerala. Using a sample of 275 coconut farmers selected from Calicut and Malappuram districts, the study showed that risk do affect irrigation adoption decision by the sample farmers. Probability to get higher profit and the variance of profit were found to have positive effect on irrigation adoption decision. Whereas chances of downside risk and extreme events were found affecting irrigation adoption decision negatively. Thus, risk factor was found to have a significant effect on farmers' decision to adopt irrigation or not. The study stressed on the need to have effective risk management mechanisms accessible to farmers so that the chances of extreme losses can be minimized, and it will motivate farmers to adopt better management practices like irrigation in order to get higher returns.

Keywords: Risk, Coconut, Irrigation, Adoption

Irrigate or not to irrigate ? – Do risk factors influence coconut farmers' irrigation decisions ? Evidence from Kerala, India

Introduction

The fourth industrial revolution (4IR) is bringing drastic changes in agriculture in multiple ways, in order to make farming more efficient, sophisticated and remunerative. A large number of new technologies will become available to people engaged in farming and related activities. Many of them are already in use, like: i) satellite and unmanned vehicle imagery – which is very much helpful in farm planning, mapping crop health, etc. ii) global navigation satellite systems (GNSS)- that helps in efficient land use, crop scouting and efficient use of inputs by identifying the exact locations that are in need of particular input (fertilizer, irrigation, pesticides, etc.), iii) unmanned aerial vehicle (UAV) transportation (drone-driven logistics)- for quick transport of objects to remote areas, iv) internet of things (IoT) – which helps to gather data through sensors and helps in crop scouting, v) weather modelling, vi) irrigation systems – which are automatic and remotely controlled, with high precision on location and quantity to be irrigated, vii) gene editing with the help of Artificial Intelligence, viii) blockchain and traceability and ix) artificial intelligence (AI) and machine learning. By transforming farming into smart-farming with the help of technology, 4IR brings advanced and sustainable changes for both production and agroprocessing (Alonsoperez et al. 2018; Ane and Yasmin, 2019).

Adoption of these sophisticated technologies is expected to benefit our farming community immensely. But we can't expect all farmers to adopt these technologies immediately as and when they become available to them. Our past experiences underline this. Farmers' adoption decisions of new technologies and better management practices are being determined by diverse factors (Namara et al. 2007; Mango, 2018, Liu et al. 2018). Past studies show that rate of adoption of recommended practices and technologies were not uniform across geographical locations, and were low in many areas (Nair et al. 2011; Aker, 2011; Abey et al. 2017). Disparities in adoption rates may put non-adopters in disadvantageous position and thus will widen the income gap. Also, time lapse for adoption may take away many potential benefits and may hinder the path for growth and development. It is important to address various issues that is creating barriers for adoption. Then only our society can enjoy benefits of these scientific advancements.

Agriculture in a developing country like India is mostly dominated by small holder farmers, and is often lagging behind developed countries in access to and rate of adoption of many latest technologies and better management practices. This creates a disadvantageous position for our farmers in realising reasonable return from farming activities (Aryal et al. 2017). Among the various factors that influence decision to adopt a technology or recommended management practice, risk factors hold an important place. But studies addressing the role of risk on these adoption decisions are scarce (Ghadim et al. 2005; Marra et al. 2002; Ghadim and Pannell, 1999) – especially in the Indian context. Uncertainty associated with adoption of any kind of agricultural technology has two features: first, the perceived riskiness of future farm yield after adoption and second, production or price uncertainty related to farming itself (Koundouri et al. 2006). If poor people are risk averse, they will be reluctant to invest in modern technology because that involves taking risks, thus they will remain poor in absence of mechanisms to minimize the downside effects. Hence, addressing the issue of effect of risk on technology adoption is much relevant to ensure growth and development and to help the resource poor farmers to get out of poverty (Yu et al. 2014; Juma et al. 2009; Koundouri et al. 2006; Shajari and Bakshoodeh, 2006).

Coconut is an important plantation crop with high economic value globally. India is a leader in coconut production, falling only behind Indonesia and Philippines. In India, coconut is cultivated in 17 states and three Union Territories, and is contributing almost 31 percent of the world coconut production. Coconut products including coir bring in foreign exchange of around Rs 3000 crore to the country. Kerala - a coastal state in India - is leading in coconut production in India. Coconut dominates in the total area cultivated in Kerala, which accounts for nearly 40 percent of net sown area in the state. Also, among all crops it is the second largest contributor to the state income. In the all-India level, Kerala accounts for highest area under coconut (37.02 percent) and also highest in production (31.16 percent). Irony is that it comes only 6th in productivity with only 9664 nuts/ha, whereas studies shows that it can be improved to a much higher level by better management.

Coconut farming is an important livelihood activity of the rural farm households of Kerala, and is facing a number of risks. Turbulence in the world market, liberalization and climate change are playing a greater role in putting the farmers in a much risky environment. Studies shows that coastal areas are the most vulnerable to vagaries related to climate change (Gangwar, 2013; Addo, 2013). Kerala is a coastal state with a fragile and unique ecosystem, which is highly vulnerable to adverse effects of climate change (Smitha, 2020; Jacb, 2019; Sundaresan, 2011). Apart from this, being a perennial crop there is lack of flexibility in the cropping pattern in order to adjust with any unfavourable situations (GoK, 2013).

Irrigation is an important management practice crucial for ensuring better yield from coconut. Though Kerala is a state that receive good monsoon showers, there is a dry summer and it causes yield reduction in this perennial crop. Studies show that by providing adequate irrigation, yield can be increased significantly (Thampan et al. 2004). Though Kerala tops in production of coconut in the country, yield level of coconut palms in the state is not satisfactory. One reason for this is lack of proper management including lack of adequate irrigation (Surendran et al. 2019; Jnanadevan, 2017; Carr, 2011). Though irrigation is this much important to have a better yield, many farmers are still not irrigating their coconut palms. Among many reasons, risk may be one factor influencing farmers' decision to adopt irrigation.

Studies from different places have showed the influence of risk on adoption of technology/ management practices by farmers (Koundouri, 2006; Juma et al. 2009; Yu et al. 2014; Ward and Singh, 2014; Shiammotto et al. 2014). Though coconut farmers faces multiple risks, and there is much gap in irrigation adoption even after various support measures, there is dearth of studies addressing role of risk on coconut farmers irrigation adoption decision – especially in a leading coconut producing region like Kerala. This study is an effort to address this issue of influence of risk factors on farmers' irrigation adoption decision in Kerala.

Conceptual Framework

Following Koundouri et al. (2006) and Juma et al. (2009), we assume that farmers are risk averse and utilize a vector of conventional inputs X, along with irrigation water X_w, to produce a single output q. The farmer incurs production risk because yield is affected by uncertain climatic conditions. The risk is captured by a random variable, ε, whose distribution *G(.)* is exogenous to the farmer's actions. Let p denote output price and r the corresponding vector of input prices. Farmers are assumed to be price takers in both the markets, and p and r are assumed non-random. Hence climatic variables are the only source of risk we consider here. The production function is given by:

$$q = f\,[x_{w,}\, x / h] \ldots\ldots(1)$$

Where q is output, x_w and x are irrigation water and other standard inputs that are conditioned by plot and household characteristics, *(h)*[1]. This function is assumed to be well behaved, continuous, and twice differentiable.

Allowing for risk aversion, the farmer's problem is to maximize the expected utility of profit as follows:

$$\max_{X,Xw} E[U(\varpi)] = \max_{X,Xw} \int \{U[pf(\varepsilon, x_w, x) - r_w x_w - r'x]\}dG(\varepsilon) \ldots\ldots\ldots\ldots\ldots (2)$$

Where U(.) is the *von Neumann-Morgenstern* utility function. The first order condition for the irrigation water input choice is given by the following:

$$E[r_w U'] = E\ \{p\frac{\delta f(\epsilon, x_w, x)}{\delta x_w}U'\} \iff \ldots\ldots\ldots\ldots (3a)$$

$$\frac{r_w}{p} = E\{\frac{\delta f(\varepsilon, x_w, x)}{\delta x_w}\} + \frac{cov[U'; \delta f(\epsilon, x_w, x)/\delta x_w]}{E[U']} \ldots\ldots\ldots (3b)$$

Where $U' = \delta U(\varpi)$. For a risk neutral farmer, the ratio of input price to output price, r_w/p, equals the expected marginal product of irrigation water input. This is represented by the first term in the right-hand side of the equation (3b). If the farmer is risk averse, the second term in the right-hand side of (3b) is different from zero and measures deviations from the risk-neutrality case. This term is proportional and is opposite in sign to the marginal risk premium with respect to the irrigation input.

In the absence of risk and market imperfections, the optimal solution for the irrigation input would depend mainly upon the input and output vectors. However, in the presence of risk aversion and market imperfection, the optimal solution would also depend on the shape of functions U(.), f(.), and G(.), and household endowments.

Solving equations (3a) and (3b) is empirically difficult. In order to avoid this issue, we used a moment-based approach as proposed by Antle (1983; 1987). According to this approach, maximizing the expected utility of profit with respect to any input is equivalent to maximizing a function of moments. We estimated the first four sample moments of the profit distribution of each farmer, namely the mean, variance, skewness and kurtosis coefficients and included them as our covariates in analyzing the irrigation adoption decision with the help of a traditional discrete choice model.

Empirical Methodology

The econometric estimation of impact of risk on adoption of irrigation by coconut farmers is conducted in two steps. First, we estimated risk measures for each farmer by computing the first four sample moments of the profit distribution, namely, the mean, variance, skewness, and kurtosis coefficients. After that we incorporated the estimated moments in a traditional discrete choice model, along with other farmer's characteristics in order to analyze how risk factors affect the decision to adopt a better management practice like adoption of irrigation.

The first four moments of the profit distribution were derived through a sequential estimation procedure. Firstly, profit was regressed against a set of inputs, which gave the 'mean' effect. The general model is given as:

$$\pi_i = f\,(x_{wi}, x_i,\, z_i; \beta) + u_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Where, i = 1…….N denotes individual farmers in the sample, π is the profit per palm, x is the vector of variable inputs, z is the vector of extra shifters including farmers characteristics and farm specific characteristics. u is the error term.

For the present study, the model for coconut farmers is specified as:

$$PROF = \beta_0 + \beta_1\, PCM + \beta_2\, NT + \beta_3\, MEXP + \beta_4\, FEXP + \beta_5\, IREXP + \beta_6\, LEXP + \beta_7\, HHS + \beta_8\, IG + \beta_9\, AGE + \beta_{10}\, EDU + \beta_{11}\, FQEXT + \beta_{12}\, MMEXP + U \;\ldots\ldots\ldots\;(5)$$

Where,

PROF = Profit/ palm/ year (Rs)

PCM = Producer Company membership status (1 for member, 0 otherwise)

NT = Number of trees

MEXP = Manure expenditure (Rs/palm/year)

FEXP = Fertilizer expenditure (Rs/palm/year)

IREXP = Irrigation expenditure (Rs/palm/year)

LEXP = Labour expenditure (Rs/palm/year)

HHS = Household size (Number)

IG = Income group (I for APL, 0 for BPL)

AGE = Age of farmer in years

EDU = Education of farmer in years

FQEXT = Frequency of extension contact in score for frequency of visit

MMEXP = Mass media exposure in score for frequency of exposure

U = Error term

The explanatory variables are assumed to be exogenous and hence the ordinary least square estimation of (4) will give consistent and efficient estimates of the parameter vector β. Then, the j[th] central moment of profit (j = 2……m) conditional on input use is defined as:

$$\mu j(.) = E\{[\pi(.) - \mu j]^j\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (6)$$

Where, μj represents the mean or first moment of profit. Thus, the estimated errors from the mean effect regression ($\hat{u} = \pi - f(x_{wi}, x_i, z_i; \hat{\beta})$) are estimates of the first moment of the profit distribution. The estimated errors û are then squared and regressed on the same set of explanatory variables.

$$\hat{u}_i^2 = g(x_{wi}, x_i, z_i; \delta) + \tilde{u}_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The application of OLS on *(7)* provides consistent estimates of the parameter vector δ and the predicted values of $\hat{u}_i^2$ are consistent estimates of the second central moment of the profit distribution. We follow the same procedure to estimate the third and fourth central moments, by using the estimated errors raised to the power of three and four, respectively, as dependent variables in the estimated models. The four estimated moments along with farmer's structural and demographic characteristics are then incorporated into a discrete choice model of adoption of mineral mixture. Probit model was used in this stage and the model is given as:

$$Pr[Yi = 1] = \phi\ (z_i'\alpha + m_i'\alpha^m)\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where vector z is a vector of regressors including all structural and demographic characteristics, m is the vector of the first four profit moments that introduce uncertainty into the model and α is a vector of corresponding parameters to be estimated.

The model used for coconut farmers is:

$$IRGN = \beta_0 + \beta_1\ M1 + \beta_2\ M2 + \beta_3\ M3 + \beta_4\ M4 + \beta_5\ NT + \beta_6\ HHS + \beta_7\ IG + \beta_8\ AGE + \beta_9\ EDU + \beta_{10}\ FQEX\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where,

IRGN = Irrigation status (1 for irrigating, 0 otherwise)

M1, M2, M3 & M4 = First four moments (Mean, Variance, Skewness and Kurtosis)

NT = Number of trees

HHS = Household size

IG = Income group (I for APL, 0 for BPL)

AGE = Age of farmer in years

EDU = Education of farmer in years

FQEX = Frequency score of extension contact

The Data

The present study is based on primary data extracted from a broader data set prepared for a study supported by Indian Council of Social Science Research. Sample for the present study consists of 275 coconut farmers from two districts of Kerala: Calicut and Malappuram, during 2017-18.

Kerala is the leading coconut producing state in India, and the farmers in the state are facing vulnerability to multiple risks. Thus, Kerala was purposively selected for the study. Calicut and Malappuram – two major coconut producing districts in the state were selected, and respondents were selected randomly from a cluster of villages from each district, after satisfying multiple criteria like irrigation status, Producer Company membership, etc. The primary data pertaining to agro-socio-economic variables of coconut farmers and farming details were collected by personal interview method, using structured, pre-tested interview schedule.

Table 1: Summary statistics of variables used

Variable	**Mean values**
Number of respondents	275
Profit/palm (Rs/year)	226.25
Number of trees	49.70
Irrigation status	Irrigating: 106, Not irrigating: 169
PC membership	Member: 129, Non-member: 146
Manure expenditure/ tree (Rs/year)	48.7
Fertilizer expenditure/ tree (Rs/year)	14.17
Irrigation expenditure/ tree (Rs/year)	1.80
Labour expenditure/tree (Rs/year)	317.86
Family size	4.43
Age of farmer (Years)	56.93
Education (Years)	8.60
Frequency of extension contact	5.92
Mass media exposure	3.8

Summary statistics of the variables used are presented in Table 1. Among the 275 respondents, 106 farmers were irrigating and 169 farmers were not irrigating their coconut palms. Also, among the respondents 129 farmers were members and 146 farmers were non-members of coconut Producer Company. On an average, farmers were having 50 palms, and the average profit/palm was found to be Rs.226.25/year. On an average, respondent farmers were having 8 years of education, and the average age was 59.6 years. Farmers were not applying adequate quantity of manures or fertilizers, and thus the average amount spent on these were low. Monitoring and Evaluation Division (2016) also had commented on the low rate of fertilizer and manure application by coconut farmers in Kerala, owing to less profit realized from the crop.

Results and Discussion

In the first step, profit/palm was regressed on different farm and farmer related variables like number of trees, manure expenditure/tree, fertilizer expenditure/tree, irrigation expenditure/tree, labour expenditure/tree, family size, income group, age, education, frequency of extension contacts and mass media contact. Results of profit function estimation are presented in Table 2.

Nearly 54 percent of variation in profit was found to be explained by the variables included in the model. Being a member of Producer Company is found to have positive effect on the profit obtained by the farmer. Similarly, irrigation expenditure and expenditure on organic manure was found to affect profit positively. Though Kerala get ample rainfall, summer season is affecting coconut yield drastically, and many studies have shown that irrigation will help to achieve higher yield. Same result we could see in our case also. Basin opening and applying organic manure prior to monsoon season is a common practice being adopted by coconut farmers; and the results shows application of these organic manures contributes positively to profit by means of increased nut yield and quality. Fertilizer expenditure was found to have no significant effect on the profit – it can be because many of the farmers were not applying fertilizers, and even if they apply it was found to be meagre. Labour expenditure is found to affect negatively; it may be because of the high wage rate. Labour shortage and high wage rate is a major issue that all farmers in the area were complaining about. Age, education and frequency of extension contact- the variables which are expected to enhance farmer's knowledge and expertise, is found to have positive influence on the profit obtained. As the farmer become more knowledgeable and experienced, it will be helping him/ her for better utilization of resources and better marketing, thus increasing the profit.

Table 2: Profit function estimates of coconut

Variable	**Coefficient**	**Standard Error**
Constant	-1.845	49.790
PC membership status	15.130**	7.334
Number of trees	0.017	0.101
Manure expenditure	0.702***	0.130
Fertilizer expenditure	0.079	0.1993
Irrigation expenditure	3.946***	1.122
Labour expenditure	-0.284***	0.050
Family size	-0.644	2.986
Income group	-1.827	7.273
Age	2.626***	0.514
Education	12.062***	2.049
Frequency of extension contact	3.452**	1.449
Mass media exposure	0.041	2.437
R^2: 56.23, Adj. R^2: 54.23		

Note: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent levels respectively

Estimated errors obtained from this regression is the first moment (mean) of profit function. These errors are then raised to the power 2nd, 3rd and 4th and regressed on the same set of explanatory variables, and the predicted values obtained from these regressions are the second (variance), third (skewness) and fourth (kurtosis) moments of the profit function respectively. These moments, along with other relevant variables are then incorporated into a discrete choice model (Probit model) of irrigating/ not irrigating to check for the effect of risk on adoption decision of irrigation.

The influence of risk on farmers' adoption behaviour is well reflected in the regression results (Table 3). All the four moments were found to be significant – mean and variance positively and skewness & kurtosis negatively. It shows that the higher the expected profit, the greater the probability that a farmer will be adopting irrigation. Farmers are driven by profit maximization and would be motivated to adopt irrigation if it is guaranteeing a higher profit. Similarly in the case of increasing variance, the probability of adopting irrigation also increases significantly. When there is higher probability of getting extreme profit values-shown by higher variance, willingness for adoption of irrigation also increases. Third and fourth moments are negatively significant. A higher probability of downside risk, represented by skewness of profit, decreases the chance of farmers' adopting irrigation. Along with the third moment, fourth moment also is negatively significant. It shows that as a result of extreme events farmers adoption decreases significantly. These results shows that farmers are not risk neutral, or risk factors has significant influence on adoption of better management practices like irrigation.

Apart from the risk variables, most of the other farm and farmer related factors also showed significant positive/ negative influence on adoption of irrigation. It is found that as the number of trees increases, adoption decision goes low. It may be because of the larger efforts/ arrangements needed for irrigating huge area. Chances of occurance of losses also may be detterring farmers with large number of trees to spend higher amount of money or efforts on management practices like irrigation. There are a number of issues like high cost of inputs, shortage of labourers, stagnating yield, price volatility etc. which the coconut farmers are facing and this creates hurdles in getting a reasonable profit in a stable manner. These might be making them cautious while diverting further resources for coconut farming. Thus farmers with more number of coconut palms may be trying to minimize the expenditure incurred and this will be negatively affecting decision to adopt irrigation.

Apart from the risk variables, most of the other farm and farmer related factors also showed significant positive/ negative influence on adoption of irrigation. It is found that as the number of trees increases, adoption decision goes low. It may be because of the larger efforts/ arrangements needed for irrigating huge area. Chances of occurance of losses also may be detterring farmers with large number of trees to spend higher amount of money or efforts on management practices like irrigation. There are a number of issues like high cost of inputs, shortage of labourers, stagnating yield, price volatility etc. which the coconut farmers are facing and this creates hurdles in getting a reasonable profit in a stable manner. These might be making them cautious while diverting further resources for coconut farming. Thus farmers with more number of coconut palms may be trying to minimize the expenditure incurred and this will be negatively affecting decision to adopt irrigation.

Similarly, income group also showed negattive relationship. It may be because most well off people among the respondants are not solely dependent on crop income, or it is not their primary activity. Thus they may not be able to put more time or money efforts in this activity and hence being in a higher income group might have negatively influenced the decision to use irrigation.

Family size was found to have positive effect which may be because of the availability of family labour. As more number of people are available, it may be easier to adopt better management practices as there are people available to look after the various activities required. This might have positively influenced decision to adopt irrigation. Information providing factors of farmer - such as education and frequency of extension contact were also found to have positive influence on adoption of irrigation. Both these factors might have helped the farmer to have a clear picture on possible incremental return if they irrigate the farm, and also might have provided with information regarding various schemes, techniques and necessary details so that they might have got encouraged to adopt irrigation.

Table 3: Probit regression to study effect of risk on adoption of irrigation

Variable	**Coefficient**	**Standard Error**
Constant	-25.194	4.820
First moment (Mean)	0.009**	0.004
Second moment (Variance)	0.007***	0.001
Third moment (Skewness)	-3.33e-04***	5.97e-06
Fourth moment (Kurtosis)	-2.07e-07***	4.17e-08
Number of trees	-0.024***	0.007
Family size	0.597**	0.250
Income group	-1.827***	0.613
Age	0.066	0.044
Education	0.521***	0.157
Frequency of extension conttact	1.051***	0.196
Log likelihood: -25.48, Prob>Chi^2: 0.000		

Note: ***, ** and * denote significance at 1 percent, 5 percent and 10 percent levels respectively

Conclusion

Irrigation is an important management practice recommended for getting higher yield from coconut palms. Even though it have potential to give higher yield, many farmers are still not adopting irrigation. Because of poor adoption rates, farmers are not able to fetch maximum profit from farming. Among a number of possible reasons, risk has a prominent place. Hence this study tried to study the effect of risk on adoption of irrigation by coconut farmers in Kerala. Chances of getting a higher profit, and also variance of profit was found to have positive effect on irrigation adoption decision. Whereas a higher probability of downside risk and chances of occurrence of extreme events were found to affect irrigation adoption negatively. Thus from the results it came clear that risk has significant effect on coconut farmers' decision to adopt irrigation. There is immense need for efficient risk management mechanisms which can avoid chances of huge losses. In the absence of such risk management mechanisms, many improved technologies and management practices may not get adopted by the farmers and thus they won't be able to get adequate economic returns from farming activities.

Acknowledgement

Authors thankfully acknowledge financial support provided by Indian Council of Social Science Research (ICSSR) for conducting the study

References

Addo, K. A. 2013. Assessing costal vulnerability index to climate change: the case of Accra – Ghana. Journal of Coastal Research, 65: 1892-1897

Abey, K. A., Blalock, G., and Berhane, G. 2017. Locus of control and technology adoption in developing country agriculture: evidence from Ethiopia. Journal of Economic Behavior & Organization, 143(2017): 98-115

Aker, J. C. 2011. Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. Agricultural Economics, 42(6): 631-647

Alonsoperez, F., Alonsoperez, V., Uruguay, C., Kruijssen, F., Tyszler, M., and Wan, S. 2018. The Fourth Industrial Revolution: benefits and threats for commodity dependent developing countries. https://common-fund.org/wp-content/uploads/2019/07/CFC-AR-2018_4th-Industrial-Revolution.pdf

Ane, T., and Yasmin, S. 2019. Agriculture in the Fourth Industrial Revolution. Annals of Bangladesh Agriculture, 23(2): 115-122

Antle, J. M. 1983. Testing for Stochastic Structure of Production: A Flexible Moment- Based Approach. Journal of Business and Economic Statistics 1(3): 192–201.

Antle, J. M. 1987. Econometric Estimation of Producers' Risk Attitudes. American Journal of Agricultural Economics, 509-522

Aryal, J. P., Jat, M.L., Sapkota, T. B., Chhetri, A. K., Kassie, M., Rahut, D. B., and Maharjan, S. Adoption of multiple climate smart agricultural practices in the Gangetic plains of Bihar, India. International Journal of Climate Change Strategies and Management. 10(3): 407-427

Carr, M. K. V. 2011. The water relations and irrigation requirements of coconut (*Cocos nucifera*) : a review. Experimental Agriculture, 47(1): 27-51

Espinoza, C.S. 2012. Production Risk and Level of Irrigation Technology. Evidence from Potato Family Farmers in Chile. Department of Economics, University of Copenhegan, Unpublished paper

Gangwar, Sneh. 2013. Climate change vulnerability and risk assessment: focusing on Coastal India. International Journal of Environmental Engineering and Management, 4(6): 605-612

Ghadim, A. K. A., and Pannell, D. J. 1999. A conceptual framework of adoption of an agricultural innovation. Agricultural Economics, 21: 145-154

Ghadim, A. K. A., Pannell, D. J., and Burton, M. P. 2005. Risk, uncertainty, and learning in adoption of a crop innovation. Agricultural Economics, 33: 1-9

GoK (Government of Kerala). 2003. Building a Sustainable Agricultural Trade Security System for Kerala. Report of the Commission on WTO Concerns in Agriculture

Jacob, J. (2019, October 25). Why global warming has left Kerala vulnerable. India Today, Retrieved from: https://www.indiatoday.in/india-today-insight/story/why-global-warming-has-left-kerala-vulnerable-1612792-2019-10-25

Jnanadevan, R. 2017. Drip irrigation for coconut in Kerala. Indian Coconut Journal, 1: 12-15

Juma, Maurice., Nyangena, Wilfred and Yesuf Mahmud. 2009. Production Risk and Farm Technology Adoption in Rain-Fed, Semi-Arid Lands of Kenya. Discussion Paper No. 09-22, Environment for Development

Koundouri, Phoebe., Nauges, Celine and Tzouvelekas, Vangelis. 2006. Technology adoption under production uncertainty: theory and application to irrigation technology. American Journal of Agricultural Economics, 88(3): 657-670

Liu, T., Bruins, R.J.F., and Heberling, M.T. 2018. Factors influencing farmers' adoption of best management practices: a review and synthesis. Sustainability, 10(432): 1-26

Mango, N., Makate, C., Tamene, L., Mponela, P., and Ndengu, G. 2018. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, South Africa. Land, 7(49): 1-19

Marra, M., Pannel, D. J., and Ghadim, A. A. 2002. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?. Agricultural Systems, 75: 215-234

Monitoring and Evaluation Division. 2016. An Analytical Study on Agriculture in Kerala. Directorate of Agriculture, Government of Kerala

Nair, S., Wang, C., Segarra, E., Belasco, E., Larson, J., Velandia, M., Lambert, D., and Reeves, J. 2011. Adoption of Precision Agriculture for cotton in Southern United States. Journal of Agribusiness, 29(2): 221-242

Namara, R. E., Nagar, R. K., and Upadhyay, B. 2007. Economics, adoption determinants, and impacts of micro-irrigation technologies: empirical results from India. Irrigation Science, 25: 283-297. DOI 10.1007/s00271-007-0065-0

Shajari, S. and Bakhshoodeh, M. 2006. Economics of Risk and Technology Adoption: Evidence from Wheat in Iran. International Conference on Policy Modeling-EcoMod2006, Hongkong, June 28-30, 2006

Smitha, N. (2020, February 17). Climate change in Kerala: Palakkad records India's highest temperature. Deccan Chronicale, Retrieved from: https://www.deccanchronicle.com/nation/in-other-news/170220/climate-change-in-kerala-palakkad-records-indias-highest-temperatu.html

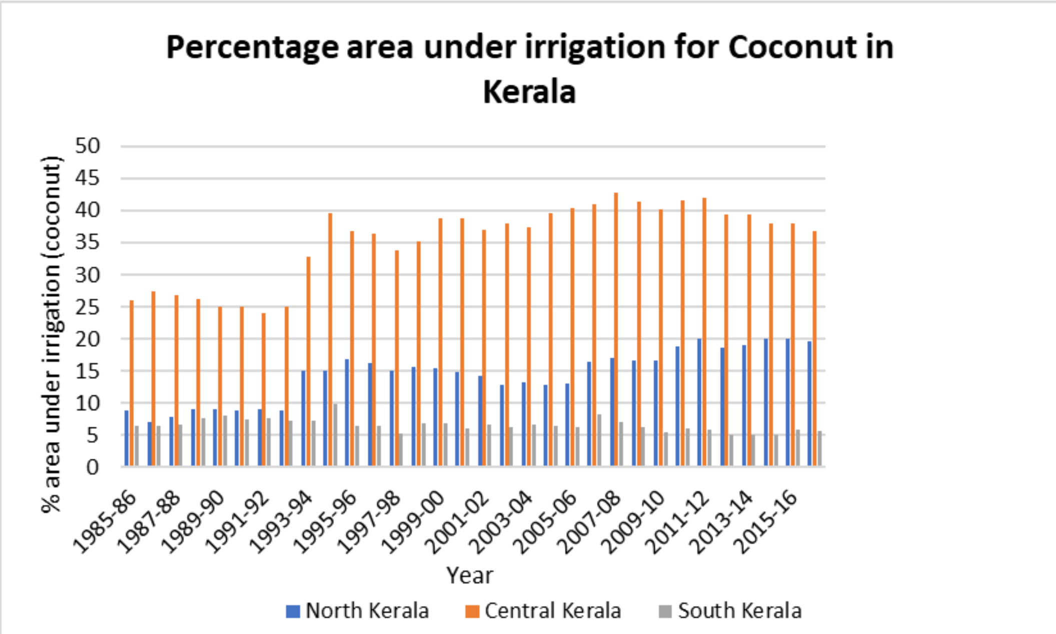
Sundaresan, J. 2011. Climate change impact – A novel initiative for Kerala. Indian Journal of Geo-Marine Sciences, 40(4): 483-486

Surendran, U., Sushanth, C. M., Joseph, E. J., Al-Ansari, N., and Yaseen, Z. M. 2019. FAO CROPWAT Model- based irrigation requirements for coconut to improve crop and water productivity in Kerala, India. Sustainability, 11(18): 5132 doi.org/10.3390/su11185132. https://www.mdpi.com/2071-1050/11/18/5132

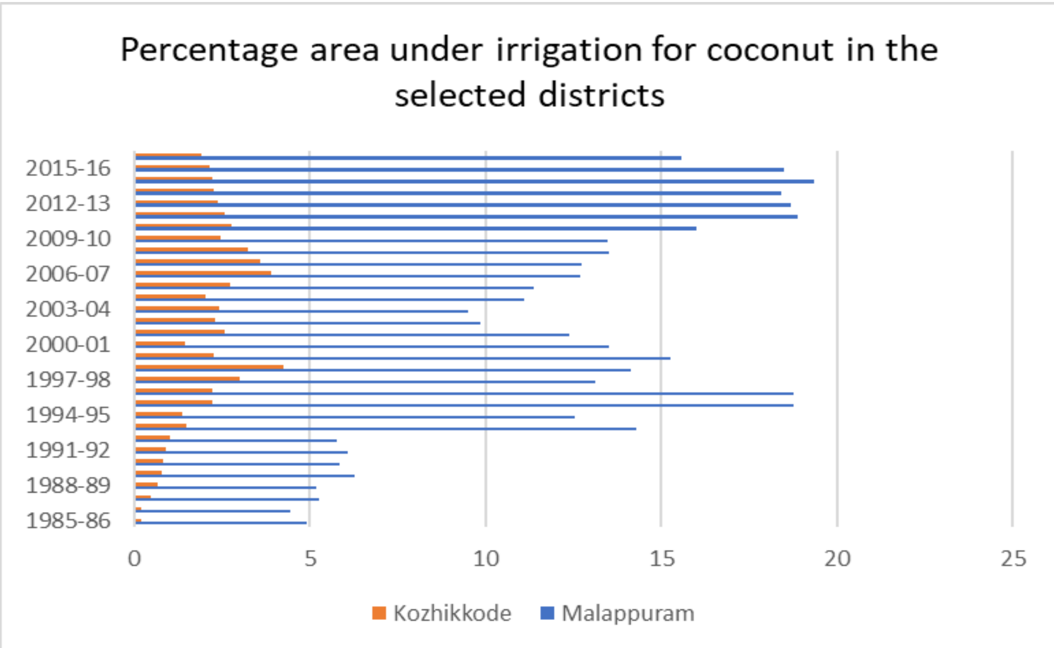
Thamban, C., Mathew, A.C and Sairam, C.V. 2004. Field Level Performance of Micro Irrigation System in Kasaragod District – A Critical Analysis. Project Report, Project Proposal No. 197/99, Central Plantation Crops Research Institute, Kerala

Yu, Xi., Hailu, Getu., and Cao, Jessica. 2014. Risk Attitudes, Social Interactions and the Adoption of Genotyping in Dairy Production. Selected Paper Prepared for Presentation at Agricultural and Applied Economics Association's 2014 AAEA/EAAE/CAES Joint Symposium "Social Networks, Social Media and the Economics of Food", Montreal, Quebec, Canada, May 28-30, 2014.

Appendix



Percentage area under irrigation for Coconut in Kerala
% area under irrigation (coconut)
50
45
40
35
30
25
20
15
10
5
0
1985-86
1987-88
1989-90
1991-92
1993-94
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
2007-08
2009-10
2011-12
2013-14
2015-16
Year
North Kerala
Central Kerala
South Kerala



Percentage area under irrigation for coconut in the selected districts
2015-16
2012-13
2009-10
2006-07
2003-04
2000-01
1997-98
1994-95
1991-92
1988-89
1985-86
0
5
10
15
20
25
Kozhikkode
Malappuram