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Technology Adaptation Behavior of Rice Farmers for Climate Resilient Agriculture

P. Muralidharan[1*], M.S. Rajeev[2], Reema Anand[3], K. Sajnanath[4], G. Lekha[5], Anjali. R. Nathan[6], T. Sivakumar[7] and Jesmi Vijayan[8]

ICAR- Krishi Vigyan Kendra-Alappuzha, CPCRI, Regional Station, Kayamkulam, Kerala 690 533, India
E-mail: kvkalapuzha@gmail.com

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ABSTRACT This paper discusses the results of Participatory Action Research on an alternate extension approach called the socio-ecological extension system (SEES) implemented in Kuttanad, Kerala, India. It evaluated its capacity to promote climate resilient agriculture in the area by facilitating technology adaptations. It used the Technology Adaptation Index (TAI) to measure technology adaptation behavior of partner farmers (PF) under SEES. The TAI score of conventional farmers was also used to have a comparative analysis. The TAI of PFs showed uniformly high values compared to farmers under conventional extension on all three dimensions of adaptation measured, that is, context (29.57), content (26.0) and effect (28.50). It implied that the flexible framework for technology management under SEES with participatory communication and eco-friendly resource use as defining features has the potential to promote climate resilient agriculture in vulnerable agro-ecosystems. It can effectively address the issue of integration of natural and social processes with technological innovations to suit field contingencies.

INTRODUCTION

Extreme diversities that exist between agro-ecological zones and farming systems is a great challenge faced by extension systems world over in promoting climate resilient agriculture. Conventional linear systems of extension with a top-down approach have serious limitations to support farmers operating in these vulnerable contexts to adapt, increase their local knowledge and scale-up innovation that will enable them to become more resilient (Ewbank 2015). Therefore, flexible alternate extension approaches that promote technology management through situation specific adaptations and natural resource conservation are needed to support farmers operating under climate vagaries. This assumes paramount importance for protecting livelihoods of small and marginal farmers especially in geographically diverse countries like India (GOI 2015). Identification of adaptation measures and possible co-benefits in the contexts of diverse agricultural systems, indigenous knowledge and scale differences are often, the suggested prerequisites for evolving targeted interventions specific to address the vagaries (Vermeulen and Dinesh 2016). This paper discusses the evaluation of an alternate extension approach called the socio-ecological extension system (SEES) implemented in the Kuttanad rice production system, Kerala, India in identifying the farmer adaptations.

Kuttanad is one of the few regions of the world that produces rice at below mean sea level in the tropics. It forms a unique ecologically fragile bio-geographical unit located mostly in the Alappuzha district of the state. The vulnerability of the production system is attributed to the problems of water logging and soil acidity aggravated through climate stress and indiscriminate input use. Erratic summer rains and monsoon floods in the low-lying paddy fields and summer moisture stress in the uplands often cause extensive crop damages in the area. Intensive input use aimed at improving biophysical resilience has worsened the situation raising serious concerns about the sustainability of the system (Gangadharan et al. 1998). However, the uniqueness in biogeography and associated social factors and institutions has earned it the status of a Globally Important Agricultural Heritage System (GIAHS) by the FAO in 2013. Heri-

Address for correspondence:
P. Muralidharan,
ICAR- KrishiVigyan Kendra-Alappuzha,
Regional Station,
Kayamkulam, Kerala 690 533, India
Mobile: +919496167382, 0479 2449268 CPCRI,
E-mail: muralibinoo@gmail.com,
mpayani@yahoo.com

tage status shifted the focus of development programs to ecological restoration and sustainable development. But the conventional extension models in place were not successful enough to revive the inherent natural and social processes. This serious mismatch between the agricultural production concerns and demands of helping the farmers cope with climate change and threats to natural resources depletion were addressed through SEES in the study (Muralidharan et al. 2013).

The SEES functioned as a bottom-up approach that integrated sociological network theory, institutional economics and systems theory into a participatory framework aimed at promoting agro-system resilience (Parson 1951; Glaser et al. 2008 and Faure et al. 2012). As studies suggested flexible extension systems enabled adaptation of natural, social and technological innovations as per the vulnerability perceptive and decision-making of farmers to suit field contingencies (Belliveau et al. 2006).

Objectives

It is in this backdrop that the paper analyzes how the flexible framework for technology management under SEES, which had participatory communication, and eco-friendly resource use as the defining features enables technology adaptation. It describes the technology adaptation behavior of the farmers operating under SEES and its effect on rice production in the region. A comparative analysis with farmers under the conventional extension system is also attempted to prove the effectiveness of the SEES in providing a flexible platform of learning, adaptation and innovations. The implications of using the approach in complex and diverse agricultural production system to combat climate vagaries in contrast to the conventional system are also highlighted.

METHODOLOGY

Participatory action research involving selected farmers organized in groups was used in the study. Facilitated experiential learning based field demonstrations of resource conserving technology packages for climate resilience selected through Focus Group Discussions (FGD) of farmers and experts were conducted in the fields of selected farmers for three crop seasons from 2011-2014.

Study Area

The study was confined to the low-lying wetlands of *Kuttanad* called *Padasekharams* (polders). *Padashekarams* are defined as continuous stretches of land reclaimed for rice cultivation by dewatering using indigenous devices and bounded by waterways or other natural features (Aravindakshan and Nair 1990). The polders varied in sizes and ranged from 4.0 - 960 hectares.

Sampling Design

Muttar village (Fig. 1) in the Veliyanad Block of Alappuzha district (9°24’ N and 76°30’E) has been purposively selected owing to its typical representation of Kuttanad system in agro-ecological peculiarities, remoteness from mainstream extension activities of other agencies and responsiveness of farmers. The village, with a geographical setting of 2 meters below mean sea level is vulnerable to frequent monsoon floods (June to September) and only one annual crop of paddy is possible. Inherent soil acidity aggravated by moisture stress and saline water intrusion in summer months also affects the crop. In addition, social and technology use factors with direct influence on profitability of rice production in the region like labor shortage, high seed rate use, indiscriminate use of fertilizers, and plant protection chemicals also affected the crop production.

Eleven *Padashekarams* were randomly selected for the study that constituted approximately ten percent of the total number of *Padashekarams* of the selected village. Based on their willingness to participate in the demonstrations, 75 farmers were purposively selected as Partner Farmers (PF) from these selected *Padashekarams* after systematic interactions and orientations. A profile of the socio-ecological and edaphic properties of the selected *Padashekarams* is presented in Table 1. The annual mean rainfall of the area is 2,809 mm and the normal temperature ranges from 28.8 to 32.7°C.

PFs were trained on the evolved technology package and the calendar of activities was prepared with day zero as the day of sowing. The schedule had technology protocols prepared that included pre zero day activities including seed treatments and related practices. Each was provided with a field book to record every oper-

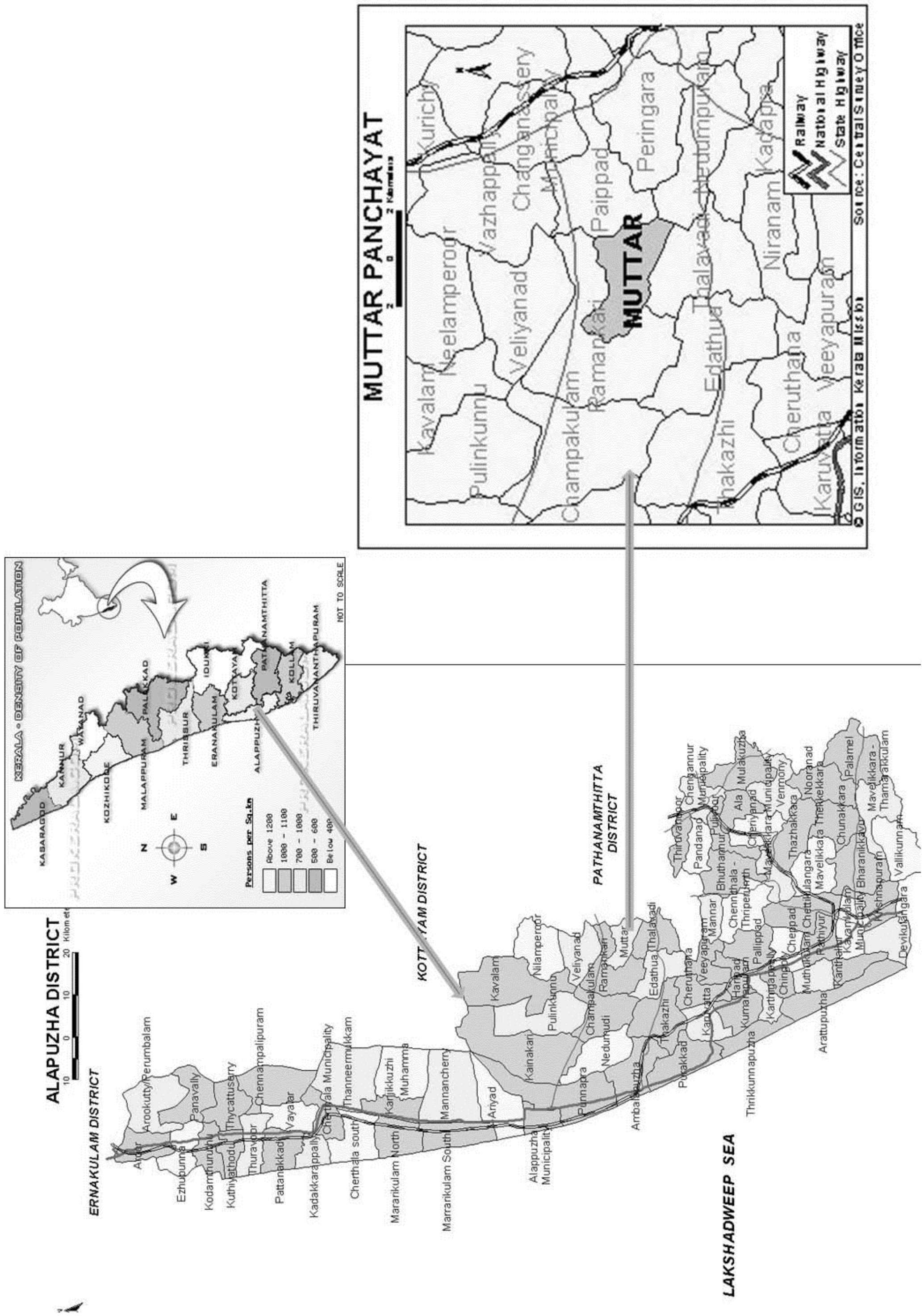

Fig.1. Location map of Muttar Village

Table 1: Profile of selected *Padashekarams* of Muttar Village

S. No.	Name of Padasekharam	Total Area selected area) (ha)	Total no. of farmers (selected farmers)	Average farm size (ha)	Average age of farmers (years)	Average farming experience (years)	Average rice productivity (kg ha^{-1})	pH	Soil properties: EC (dSm^{-1})	Org. C (percent)	Avail.P (kg ha^{-1})	Avail. K (kg ha^{-1})
1	Kizhakkemunduveli-paramb	25.72(2.2)	50(12)	0.5	55	30	5500	4.1	0.57	1.01	4.41	47
2	Kumaranchira	6.4 (1.0)	7 (01)	0.9	60	35	5000	4.4	0.28	1.2	3.7	35.5
3	Cherikalakam	85.21 (2.8)	125 (05)	0.7	56	30	5250	4.6	0.24	1.41	3.08	51.13
4	Paruthikkattussery	29.0 (4.0)	45 (06)	0.6	60	30	5250	4.5	0.25	2.14	2.16	57.71
5	Ambalappadam	49.65 (2.4)	68 (05)	0.7	54	22	5750	5.1	0.08	2.04	5.48	15.14
6	Mulavanakkari	35.83 (14.56)	43 (17)	0.8	60	30	5750	4.7	0.16	1.19	3.2	35.24
7	Kuzhiyanadi	103.3 (1.0)	145 (03)	0.7	65	34	5250	4.9	0.25	1.02	3	46.37
8	Kuttivalavu	2.99 (0.48)	7 (01)	0.4	55	10	5750	4.9	0.65	1.74	2.58	62.94
9	Chebilayam	23.36 (1.4)	33 (02)	0.7	58	28	5250	5.4	0.06	1.93	7.6	17.36
10	Ramankaripadavu	54.08 (0.4)	65 (01)	0.8	48	20	5750	4.8	0.15	2.58	7.6	25.8
11	Kalayankari	13.2 (9.2)	23 (22)	0.6	54	20	5250	4.0	0.43	1.84	4.78	131.7
	Total	428.74 (39.44)	611 (75)	-	-	-	-	-	-	-	-	-

Source: Records of Local Extension Office ation taken up from land preparation to harvest along with quantity and expenditure towards inputs and labor. Every operation from sowing was taken up as per the schedule with adaptations or no adaption as decided by the PFs as per field related climate contingencies. Researchers and field staff made regular field visits to all the selected PFs' fields and detailed field based observations were facilitated.

Selection of Technology Package for Demonstration

Components of the technology package for demonstrations were determined based on the problems identified as critical for agro-ecosystem resilience against climate variations. A focus group discussion (FGD) involving farmers and expert consultancy was used to evolve the adaptation package of technologies (Table 2). Selected interventions focused on integrated crop management in paddy incorporating the prevalent and potential production practices suited for climate resilience.

The package of selected technologies identified as critical for climate resilient agriculture were promoted through experiential learning based demonstrations in the crop seasons of 2011-2014. It followed a praxis model (learning-action-reflection-action) providing farmers with the best adaptation options through learning by doing, instructions and coping. PFs had the flexibility to make adaptations within the technology package based on their field contingency. These were documented with their perceived reasons for the adaptations in the field book and shared in the group meetings. Accepted adaptations were used in refining the demonstration package in subsequent seasons.

The original demonstration package interventions included optimization of seed rate and plant population through the use of drum seeder, use of new high yielding rice variety (HYV) Prathyasa with early maturity (105 days) replacing HYV Uma with 120 days maturity, site specific acidity-nutrient management (SSNM) based on soil testing, and eco-friendly pest and disease management through the use of pseudomonas for seed treatment, soil, and foliar applications, placement of trichocards for the control of major pests, that is, stem borer and leaf roller, light traps for pest monitoring, and use of fish amino acid against rice bugs. All critical inputs and information was made available free in the study through field days and group meetings.

Technology Adaptation Behavior

Adaptations were conceptualized as adjustments in system behavior and characteristics (includes ecological and socioeconomic) that enhance its ability to cope with actual or expected external stress (Brooks 2003; Smit et al. 2000). Following these conceptualizations, technology adaptation behavior has been operationalized for the study as anticipatory or reactive behavior of rice farmers in response to actual or expected climate stimuli and their effects in the system.

Technology Adaptation Index

The Technology Adaptation Index (TAI) was used to quantify the technology adaptation be-

Table 2: Results of FGD for delineating technology package for climate resilient rice production in Muttar

S. No.	*Perceived problems in rice farming*	*Perceived problem intensity (Percent)*	*Causes practices*	*Conventional intervention*	*Selected technology*
1	Declining profitability	50	Soil acidity and poor response to fertilizers	High use of chemical fertilizers	Soil test based fertilizer use anduse of soil ameliorants
2	High incidence of pests and diseases	30	High plant population, pest resurgence due to intensive pesticide use	Broadcasting using 150(PERCENT) of the seed rate recommended of pest control	Optimization of plant population use of drum seeder bio intensive methods
3	Crop loss during last phase due to lodging in summer rains	20	Higher plant population, weak plants anchorage	Broadcasting excess seeds, medium duration variety	Introduction of short duration variety, Use of drum seeder due to poor for seeding

havior. It measured adjustments attempted by PFs within the promoted technology package in response to perceived effect of climate stimuli. All the adjustments recorded from field books of PFs were categorized in relation to use of early warning weather information in making adjustments in seed rate, method and date of sowing, use of climate responsive varieties, dependence on agro-ecological symptoms for adjustments in critical crop activities to suit weather conditions, integration of indigenous methods in pest control, use of local resources in pest management, integrating personal experiences with soil test data in soil health management, use of field symptoms of acidity in the use of soil ameliorants, and adjusting harvest dates based on experience to avert damage from summer rains.

The adaptations documented in field books were listed under these parameters and discussed in group meetings. At the end of crop seasons all recorded adaptations were given for evaluation individually to PFs on three dimensions related to the context, content and effect on climate resilience and net returns on a five-point continuum of 1-5. Adaptations that were based on agro-ecological principles and experimental findings were given a maximum score of 5 and those for which no validating reason could be attributed was scored one. Adaptations were scored based on experience (4), opinions of other farmers, local wisdom (3) and traditions and rituals (2). Standard method of index computation in which all the three dimensions of context of adaptation, content of adaptation and perceived effect of adaptation were given equal weights was followed and is represented by equations 1 and 2 (Anonymous 2006).

$$TAI = \sum_{i=1}^{I} W_{\omega ij} \quad (1)$$

W_i= weight assigned to i^{th} indicator and for the study all the three dimensions were assumed to carry equal weights making W_i=1/n

D_{ij} is the dimension index for j^{th} person on i^{th} indicator

$$D_{ij} = \frac{X_{ij} - \min(X_i)}{\mathrm{Max}(X_i) - \mathrm{Min}(X_i)} \quad (2)$$

i=1,2.........n(n=3), j=1,2,3............k (k=75)

Calculated TAI values ranged from 8 to 40.

Biophysical variables like plant population/m^2, number of productive tillers/m^2, number of grains per panicle, and 1000 grain weight were recorded in addition to quantity of inputs used, cost incurred, pest and disease intensity and the final yield in all crop seasons. This was used to quantify the effect of the adapted technology package on overall rice production. Observations on technology management and use from another 75 farmers under conventional extension system from the area were also collected for comparative analysis.

RESULTS

Technology adaptations that were followed by PFs in the demonstration package recorded in percentage is given as Table 3. Results from the table indicated that the adaptation was highest among PFs with respect to climate responsive variety use recorded at 60.5 percent. The HYV Prathyasa included for its early maturity in the demonstration package so that the crop can escape the possible damage from summer rains towards the end of crop season. The high percent of adaptation indicated that this was rejected in favor of the popular rice variety Uma. Prathyasha shared all characteristics of Uma except shorter duration of 105 days against 120 days of Uma. However, under field conditions it lost the advantage of early maturity as duration of Prathyasa got extended to 120 days. Moreover, the increased plant height of Prathyasa caused its lodging even in slightly vulnerable situations of mild summer showers and was rejected by farmers. Therefore, the adaptation suggested by majority of farmers was accepted to refine the demonstration package by reverting to use of HYV Uma in the region in the subsequent seasons. Adjustments in soil ameliorant and fertilizer use were attempted by 10.7 percent and 9.02 percent of PFs, respectively. They used the field bleeding symptoms of iron toxicity and sparkling clarity of field water sources showing high salinity and molehills of crabs in fields indicating moisture stress as the basis for adaptation.

The TAI of partner farmers used in analyzing the technology adaptation behavior under SEES in comparison with farmers under conventional extension system is given as Table 4. The TAI presented in the table showed uniformly high values for PFs compared to farmers under conventional extension system on all the three dimensions of context of adaptation (29.57), content of adaptation (26.0) and effect of technolo-

Table 3: Technology adaptations attempted by Partner Farmers (PF) under SEES

*Category of adaptation**	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Basis of Adaptation	Direction of clouds and flowering of plants	Late maturity and lodging in final stages	Sparkling clarity of water sources and mole hills of crabs in fields	Economic Threshold in pest control	Field bleeding symptoms of Iron toxicity	Use of indicator plants like hydrilla	Easy availability and proof of experience	Earlier experience
Technology adapted	Prediction of rains to adjust seed rate and sowing	Replacing Prathyasa variety with Uma	Fertilizer application in more splits	Changes in prophylactic sprays of bioagents	Dolomite with Lime in more splits	Determination of soil fertility status and deciding fertilizer use	Adoption of local plant extracts	Early harvest to avert summer rain damage
Percentage of adaptation among PFs	6.5	60.5	9.02	2.5	10.7	1.01	4.01	6.76

*1) use of early warning weather information in making adjustments in seed rate, and date of sowing, 2) use of climate responsive varieties, 3) dependence on agro-ecological symptoms for adjustments in critical crop activities to suit weather conditions, 4) Economic threshold limits in pest control, 5), use of field symptoms of acidity in the use of soil ameliorants, 6) integrating personal experiences with soil test data in soil health management, 7) use of local resources in pest management and 8) adjusting harvest dates based on experience to avert damage from summer gy adaptation (28.50) on climate resilience. TAI score of conventional farmers was observed to be uniformly below the median score of 24 and indicated the effectiveness of SEES in promoting technology adaptations under vulnerable agro-ecosystems compared to conventional extension systems.

Table 4: Comparison of Partner farmers with farmers under conventional extension system on Technology Adaptation Index (TAI)

S. No.	*Dimensions of adaptation*	*TAI for farmer categories*	
		Partner farmers	*Conventional extension farmers (n=75)*
1	Context	29.57	23.13
2	Content	26.00	22.11
3.	Effect	28.50	20.34
	Overall	28.01	21.86

Assessment of the adapted technology package on rice production indicated reduced environmental degradation and increased net profit of PFs as evidenced by the comparison with that of the conventional farmers given in Table 5. The results from the table showed that reduced quantity of fertilizers applied based on soil test, lowered the cost on fertilizers to almost half from INR 5,119 to INR 2,710. It is also evident that the use of drum seeders for line sowing along with minor adaptations to suit weather proved to be very effective in saving the quantity of seeds and cost of application. Against the normal practice of broadcasting 150 kg of seeds per hectare, partner farmers were convinced with the use of only one fourth of this quantity. Optimization of plant population achieved through this intervention resulted in maximum number of effective tillers per hill, larger panicles, and higher number of grains per panicle ultimately leading to higher yield. A comparison of changes brought by the technological adaptations in the selected paddy production variables is given as Table 6. Results presented in the table indicated that maximum average change was recorded at 553 percent and 130.2 percent increases in the use of soil ameliorants and bio-pesticides, respectively. This change is attributed to the success of participatory interventions that aided in overcoming the practical shortcomings of these interventions in actual field situation through contingent adaptations to suit field limitations using observational skills developed by the farmers. Adaptations in fact helped resolve the mismatch between individual scientific protocols of maintaining the time gap of lime, fertilizer, and bio-agents application in field situation.

Table 5: Economics of paddy cultivation (per ha) following the adapted technology package under SEES compared to the conventional practices of the area

S. No.	*Item*	*Partner farmers (n=75)*	*Conventional farmers (n=75)*
1	*Cost of Cultivation (Rs.)*		
A.	*Inputs*		
	(i) Seed	1338	4599
	(ii) Lime (Dolomite)	2400	0
	(iii) Fertilizers	2710	5119
	(iv) Plant protection (Bio-agents/chemicals)	3247	4243
B.	*Operations (Rs.)*		
	(i) Cultivation (Sowing, input applications, weeding etc.)	18938	17580
	(ii) Harvesting and Marketing	18490	22332
	Total	47123	53873
2	Yield (kg)	7135	6939
3	Gross income @Rs.19/kg (Rs)	135565	131841
4	Net income (Rs)	88442	77967
5	B:C ratio	2.88	2.45

Based on the impact on the system properties, technological package options selected for field demonstrations were classified as resilient and adaptive technologies following Leach et al

Table 6: Changes recorded in paddy production variables of partner farmers from adapted technological package (n=75)

S. No.	*Variable*	*Average change/ha (percent)*	*Direction of change*
1.	Seed rate	81.7	Decrease
2.	Plant population per sq. m.	81.4	Decrease
3.	Soil ameliorant use	553.0	Increase
4.	Cost on lime and nutrient management	17.10	Increase
4.	Cost on PPC	44.31	Decrease
5.	Use of bio-agents	130.2	Increase
6.	Climate related crop loss	86.4	Decrease
7.	Yield	18.30	Increase
8.	Cost of cultivation	13.45	Decrease
9.	Net income	47.70	Increase

(2010). Interventions aimed at the maintenance of the functions and structure of the *Padashekarams* was designated as resilient technologies. Resilient technologies included liming and eco-friendly pest and disease management practices using bio agents. Liming helped ameliorate the inherent soil acidity of the paddy lands in the region, which indirectly increased the nutrient use efficiency and higher microbial activity in the soil. Use of bio agents like *Psuedomonas fluorescens* for prevention of diseases, and *tricho* cards for the parasitization of the larvae and thus control of the major pests like stem borer and leaf roller, helped manage the pests and diseases without the use of chemical pesticides. This indirectly resulted in the increased population of natural enemies in the eco-system and avoided environmental pollution from the use of plant protection chemicals. Soil test based nutrient application and optimization of plant population by reducing the seed rates using drum seeder were aimed at changing the structure of the system to maintain the functions and were called adaptive technologies

DISCUSSION

The results of technology adaptation behavior under SEES proved that risk reduction through technology adaptation and refinement aided climate resilient agriculture. In fact the adaptation strategies did not eliminate the risks generated by climate change but aided in transferring it through well-designed risk sharing arrangements in the form of adaptations. It strengthened the farmers' ability to manage economic impacts while retaining incentives for risk reduction (Mechler et al. 2014). Adaptation was made possible through the SEES that promoted integration of knowledge and related information, skills, technologies and attitudes in the system perspective that replaced external input use with management skills as suggested by Chizariet et al. (1999), Pretty (1995), and Cho and Boland (2004). The continuous network of information, technology backstopping and adaptation skills that were made available under the system throughout the crop season enabled effective learning and crop management resulting in higher returns as supported by the findings of Smit and Wandel (2006).

It facilitated the building of a decentralized self-learning network platform that enabled negotiation and collective decisions to combat climate stress. SEES effectively integrated agro-ecological knowledge of farmers related to rice crop production in the area, observation skills to ascertain this knowledge at field level and attitude in integrating these with available technology options in field level problem solving. Experiential learning that follows the principle of praxis, that is, reflection-action-reflection served as the key feature of SEES. It enabled strong feedback links between social and ecological concerns affected by triggering factors of available technology options, dominant ecological concerns related to nature and human behavior dictated by community relations. Participatory communication processes was another attribute of SEES that facilitated observation based learning skills in the farmers.

CONCLUSION

It is evident from the results that farmers favored risk minimization and income optimization practices of resource recycling and conserving options in contrast to the income maximization strategies promoted under conventional extension systems. Integrated use of resilient and adaptive technologies aided in reducing vulnerabilities related to soil acidity and pest and disease resurgence as is evident from the higher productivity and net returns. This was enabled through stable actor networks consisting of researchers, extension agents, partner farmers and local community representatives under SEES. Results also suggested that it facilitated experiential learning process and co-learning that eliminated technological oversight and indiscriminate input use causing environmental depletion. Participatory communication was another factor that aided effective use of farmer networks in data collection and management, providing sufficient space for reflection (praxis). However, as any knowledge intensive system, the sustainability of the results is largely dependent on the commitment of extension team and their willingness to dedicate long field hours along with support of researchers and other stakeholders.

RECOMMENDATIONS

SEES effectively enhanced the adaptive management capacity and social development at agro-ecosystem level and can be recommended to promote climate resilient agriculture. As such it assumed profound relevance for the vulnerable tropical agro-ecosystems that are mostly knowledge intensive. Moreover, the capacity to integrate socio-ecological issues along with economic growth would be a defining feature that makes it suitable in these vulnerable agricultural production systems. Adaption of technologies that showed better resilience against summer rains and monsoon floods delineated under the study also indicated promise for use under similar agro-ecosystems. However, development and popularization of field level technology adaptations using flexible knowledge sharing platforms like SEES required innovations in policies and institutions also. Retaining incentives for adaptive risk management and providing an enabling policy environment that fosters continuous networking and technology backstopping can help its popularization as a technology management tool in vulnerable agricultural production systems. Specific policy priorities that support rebuilding and expanding public agricultural extension to foster complementarities between local farming community, research and all other related stakeholders in a system perspective is also recommended.

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REFERENCES

Anonymous 2006. *Human Development Report*. New York: United Nations Development Programme.

Aravindakshan M, Nair RR 1990. *Five Decades of Rice Research in Kuttanad*. Thrissur: Kerala Agricultural University.

BelliveauS, Bradshaw B, Smit B, Reid S, Ramsey D, Tarleton M, Sawyer B 2006. Farm Level Adaptation to Multiple Risks: Climate Change and Other Concerns. *Occasional Paper* No. 27. Canada: University of Gurlph.

Brooks N 2003. Vulnerability, Risk and Adaptation: A Conceptual Framework. *Working Paper* 38. Norwich: Tyndall Centre for Climate Change Research, University of East Anglia.

ChizariM, Lindner JR, Zoghie M 1999. Perceptions of extension agents' educational needs regarding sustainable agriculture in the Khorasan Province. *Iran J Agric Educ*, 40: 20- 27.

Cho KM, Boland H 2004. Education and Extension for Multi-functional Agricultural Extension Concepts for Sustainable Agricultural Development in Myanmar. *Proceedings of 20th Annual Conference of AIAEE*, Dublin, Ireland.

Ewbank R 2015. Climate-resilient Agriculture: What Small-scale Producers Need to Adapt to Climate Change. *Time for Climate Justice*, 15. London: Christian Aid, 35 Lower Marsh.

Faure G, Desjeux Y, Gasselin P 2012. New challenges in agricultural advisory services from a research perspective: A literature review, synthesis and research agenda. *J Agri Edn Extn*, 18: 461-492.

Gangadharan C, Gopinathan P, Karippai RS 1998. *A Study Report on Paddy Land Conservation in Kerala*. Technical Expert Committee, Government of Kerala

Glaser M, Krause G, Ratto B, Wolp M 2008. Human-Nature Interactions in the Anthropogenic Potential of Socio-ecological Systems. From <http://www.dghunanoiekologie.de/pot/DGH-Mittoilungen/GAIA200801_77_80.pdf>.

Jodha NS, Singh NP, Bantilan MCS 2012. Enhancing Farmers' Adaptation to Climate Change in Arid and Semi-arid Agriculture of India: Evidences from Indigenous Practices: Developing International Public Goods from Development oriented Projects. *Working Paper Series* No. 32.Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Leach M, Scooner I, Sterling A 2010. Governing epidemics in an age of complexity: Narratives, politics and pathways to sustainability. *Global Environmental Change*, 20: 363-546.

Mechler R, Czajkowski J, Kunreuther H, Michel K E, Botzen W, Keating A, McQuistan C, Cooper N, Donnell I 2014. Making Communities More Flood Resilient: The Role of Cost Benefit Analysis and Other Decision-Support Tools in Disaster Risk Reduction. *White Paper*. Zurich: Flood Resilience Alliance.

Muralidharan P, Rajeev MS, Jissy G, Sivakumar T, Lekha G, Ravi S, Sajnanath K 2013. *Imprints – A Decade in Service to Farmers (2004 – 2013)*. Alleppey: KrishiVigyan Kendra– CPCRI.

Parsons T 1951. *The Social System*. New York: Free Press.

Pretty JN 1995. *Regenerating Agriculture, Policies and Practice for Sustainability and Self- reliance*. London: Institute of Development Studies.

Smit B, Burton I, Klein R, Wandel J 2000. An anatomy of adaptation to climate change and variability. *Climatic Change*, 45: 223–251.

Smit B, Wandel J 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16: 282-292.

Vermeulen SJ, Aggarwal PK, Ainslie A, Angelone C, Campbell BM, Challinor AJ, Hansen JW, Ingram JSI, Jarvis A, Kristjanson P, Lau C, Nelson GC, Thornton PK, Wollenberg E 2012. Options for support to agriculture and food security under climate change. *Environmental Science and Policy*, 15: 136-144.

Vermeulen SJ, Dinesh D 2016. Measures for Climate Change Adaptation in Agriculture. Messages to the SBSTA 44 Agriculture Workshops. *CCAFS Info Note*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

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