Dated 28-09-2022

NOTE

Sub: Regarding the signature of FTR for project FIN/264

As suggested by the funding agency, the FTR of the said project has to be submitted as per the prescribed format. The FTR of the said project has been submitted for your kind consideration.

Submitted for necessary action please.

Dr. S. Choudhury
PI, Fin/264

HoC, CMS — Forwarded 28/09/22

Coordinator, R&D Cell — Forwarded for n.a. pl. 28/09/2022

SO (Finance)

Receipt No. 63421
Dated 29/9/22

Financial statements have been checked & verified.
10/11/2022

Assets has been verified found in order

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	**GBPNI/NMHS-2017-19/SG 15/614**

Date of Submission:	1	5	1	1	2	0	2	2
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE

LARGE CARDAMOM AND OTHER MULTILAYER INNOVATIVE FARMING IN MENGIO CIRCLE OF ARUNACHAL PRADESH AND ITS IMPACT ON SUSTAINABLE RURAL LIVELIHOOD.

Project Duration: *from* (**28.03.2018**) *to* (**28.03.2021**).

***Submitted to*:**

Er. Kireet Kumar
Scientist 'G' and Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies, GBP NIHE HQs
Ministry of Environment, Forest & Climate Change (MoEF&CC), New Delhi
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***Submitted by*:**

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LIST OF ABBREVIATIONS

APEDA	Agricultural and processed food products export development authority
APAMB	Arunachal Pradesh agriculture marketing board
ArSLM	Arunachal state livelihood mission
CB	Capacity building
ECR	Energy consumption ratio
FCS	Farmers' cooperative society
GBPNIHESD	G.B. Pant National Institute of Himalayan Environment and Sustainable Development
HR	Human Resource
IHR	Indian Himalayan Region
ICT	Information Communication and Technology
MSME	Ministry of small and medium enterprises
NABARD	National Bank For Agriculture And Rural Development
NEC	North Eastern Council
NER	North eastern region
NERIST	North Eastern Regional Institute of Science and Technology
NMHS	National Mission on Himalayan Studies
NSIC	National Small Industries Corporation Limited
NSSH	National SC/ ST Hub
PMCSL	Paniar Multipurpose cooperative society Ltd
PV	Photo Voltaic
RKVY	Rashtriya Krishi Vikas Yojana
SL	Sustainable livelihood
TNA	Training need assessment

NMHS-Final Technical Report (FTR)

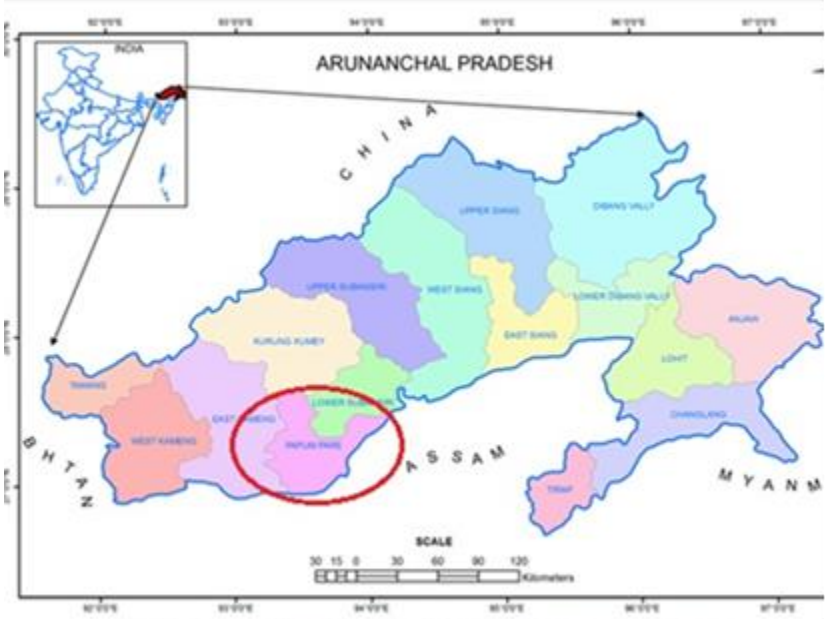
Demand-Driven Action Research Project

DSL: *Date of Sanction Letter*							
2	8	0	3	**2**	**0**	**1**	**8**
d	d	m	m	y	y	y	y

DPC: *Date of Project Completion*							
2	8	0	3	**2**	**0**	**2**	**1**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	**GBPNI/NMHS-2017-19/SG 15/614**
ii.	Type of Project	Small Grant ✓ | Medium Grant | Large Grant
iii.	Project Title	Large Cardamom and Other Multilayer Innovative Farming in Mengio Circle of Arunachal Pradesh and Its Impact on Sustainable Rural Livelihood.
iv.	State under which Project is Sanctioned	**Arunachal Pradesh**
v.	Project Sites (IHR States covered) (Maps to be attached)	 Fig 1. Map of Arunachal Pradesh and Papumpare district

vi.	Scale of Project Operation	Local	✓	Regional		Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	0.1946 (in Cr)					
viii.	Lead Agency	North Eastern Regional Institute of Science and Technology (NERIST), Itanagar, Arunachal Pradesh.					
	Principal Investigator (PI)	1. Dr. Shibabrata Choudhury, Assistant Professor, Centre for Management Studies, NERIST.					
	Co-Principal Investigator (Co-PI)	1. Dr. Saibal Chatterjee, Professor, Department of Electrical Engineering, NERIST. 2. Dr. Adikanda Parida, Assistant Professor, Department of Electrical Engineering, NERIST.					
ix.	Project Implementing Partners	1. G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Itanagar, Arunachal Pradesh. 2. Department of Food Engineering and Technology, Tezpur University.					
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	1. Er. Mahendra S. Lodhi, Scientist, GBPNIHESD, North East Unit, Itanagar. 2. Dr. Wishfully Mylliemngap, Scientist, GBPNIHESD, North East Unit, Itanagar. 3. Dr. Satish Chandra Arya, Scientist, GBPNIHESD, North East Unit, Itanagar. 4. Dr. Kshirod Kumar Das, Assistant Professor, Department of Food Engineering and Technology, Tezpur University.					

2. Project Outcomes

2.1. Abstract

Large cardamom is a major cash crop for the Mengio circle of district Papumpare, Arunachal Pradesh. Cardamom farming has been popular amongst all the inhabitants of the region within a span of six years. The farming activities are not very labor intensive, hence most of the activities carried out by the woman. However, due to the ignorance of the farmers, non-formalized marketing network, less coordination amongst the farmers, they are not able to harness the proper value of the cardamom. Ultimately, the farmers sell these products to the intermediary at a very nominal price. Though they cultivate with very less chemical usage, still they are not able to receive the proper price for 'organic farming'. Informal marketing strategies, improper storing, and packing facility create constraints for the farmers of this region. The peoples of this region have stopped livestock farming, due to the problem of fencing. The project mitigated the issues related to multi-layer cultivation through proper measures. The proposed project has given livelihood to the woman farmers through the elimination of the intermediary with the help of cooperative type of the organization to market their product in different regions of the country. The project has also trained the farmers to become the seller of the cardamom in the market place with time-to-time help from the expert panel. The project offered the farming community of the nearby region as one of the model for implementing in the nearby region. The profitability can boost up to consider the sustainable growth of this indigenous northeast people while not compromising the environmental issues. In order to save time and money, the cardamom farmers used to cut down the trees for the cardamom farming. Therefore, apart from the livelihood of the farmers of this region, the project also emphasized on deforestation, and soil erosion caused due to the cardamom cultivation. Which can stop dangers of landslides caused due to soil erosion during the rainy season. Usage of woods for drying of cardamom has also been a cause of creating air pollution; the project formulated the mechanized drying facility to overcome the same. Three important parameters that affect the system performance of heat pump assisted solar dryer are solar radiation, compressor speed and the total load placed in the drying chamber. The other processing factors on which the design of a solar dryer depends are temperature of air, relative humidity of air, moisture content of the product, amount of product to be dried, time required for drying and availability of auxiliary energy. In this process the solar collector acted as the evaporator of the heat pump system. Solar assisted heat pump systems consist of: i) Solar collector, ii) Heat exchanger as condenser, iii) Thermostatic expansion valve, and iv) Compressor. The organic farming can encourage eco-tourism through site visit. The reporting of the project would be on the Triple Bottom Line (TBL) considering economic, social, and environmental contexts of the region.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
	Profitability augmentation for the marginal farmers	• 03 workshop with the theme of “roadmap for livelihood” was organized. • 03 “workshop on cooperative farming society for the nearby cluster villages”, and • 07 “workshop on regulatory framework of cooperative farming society” were organized. • Registration of a total of 100 farmers under the Paniar Multipurpose cooperative society Ltd and selling of products under the farmers’ cooperative society banner for the financial year 2022 at a commercial scale.
	Socio-economic development & incorporation of entrepreneurial skill sets	• 05 workshops on “Awareness on Indian standards relevant to agriculture and food department”, • 05 workshops on “entrepreneurship development program on in large cardamom and other multilayer farming”, • NMHS sponsored a National seminar on tribal empowerment through the entrepreneurship of indigenous produced products -2019, May 9-10, 2019 at NERIST in collaboration with Tezpur University, and the Northeast regional centre of Govind Ballabh Pant 'National Institute of Himalayan Environment(NIHE).
	Creating importance of environmental awareness through sustainable farming	• 08 workshop on climate-resilient agricultural practices” were carried out.

2.3. Outputs in terms of Quantifiable Deliverables

S. No.	Quantifiable Deliverables	Monitoring Indicators	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1.	Augmenting green source of income for the lower income group by large cardamom farming in 3 villages;	Solar energy park demonstration to 30 farmers from 5 different villages of Mengio circle of Arunachal Pradesh.	Alternate source of green energy for livelihood at affordable price.	
		2 Exposure to electric drying process 30 number of farmers from 5 different villages of Mengio circle of Arunachal Pradesh.	Reducing carbon emission by cutting and burning of trees.	
		1 No. of orientation program conducted theme 'modern Farming practices'. Total 30 Nos. of individuals attended the said program of Mengio circle of Arunachal Pradesh.	Modern farming techniques for 30 farmers from 5 different villages of Mengio circle.	

		1 no. trip organized modern farm machinery equipment at Agriculture Engineering Lab. 02 awareness on environment awareness camp was organized under the theme of “know your planet and save your planet”.	Green economy awareness for 30 farmers from 5 different villages.	
2.	Development of entrepreneurial skill sets amongst the 30 local inhabitants;	1. A village-level committee was formed and a total of 10 Nos. individuals were selected as coordinators at the village level. 2. Training of Trainers (ToT) conducted successfully. A total of 10 farmers were inducted for this training at NERIST. 3. 12 Nos. of village	Paniar Multipurpose cooperative society Ltd and selling of products under the farmers’ cooperative society banner for the financial year 2022 at a commercial scale. Formation of farmers’ cooperative with 100 members. Beneficiaries: No. rural youth ST male: 60, No. of ST woman: 40, Total ST No:100.	

		sensitization program, 14 Rapid Rural Appraisal.	Started selling packaged large cardamom, and other multi layer farming products at nearby markets. Income at initial level is not significant.	
3.	Developing role model for other collaborative farming practices.	15 number PG dissertations submitted. 04 number of Ph.D at the final stage of process. Journal publications: 03 numbers (01 SCI + 01 Scopus + 01 Web of science). International Conference Proceedings (04 Scopus + 02 SSRN). Policy framework/ draft (No.) for assisting state agencies on Innovative	Work is being documented for future practice and research implications related to Policy framework, innovative farming; sustainable rural livelihood; Eco-preneurial Skill Development; Collaborative Farming; etc.;	

		farming; Sustainable rural livelihood; Eco-preneurial Skill Development; Collaborative Farming; etc.; Other Publications and Knowledge Products (Nos.).		

2.4. Strategic Steps with respect to Outcomes

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology developed	Renewable-based electric drying of large cardamom.	
2.	New Models/ Process/ Strategy developed	Renewable based electric dryer developed.	
3.	New Species identified	NIL	
4.	New Database established	NIL	
5.	New Patent, if any	NIL	
	I. Filed (Indian/ International)		
	II. Granted (Indian/ International)		
	III. Technology Transfer(if any)		
6.	Others (if any)		

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology	Renewable-based electric dryer developed.	01 no of unit available at the institute for the training purpose for farmers.
2.	Diffusion of High-end Technology in the region	Solar PV to address rural electrification for better livelihood.	A small energy park is installed for training and utility purpose.
3.	Induction of New Technology in the region	GRID connected solar PV-based electrification.	Small energy park is installed with training and utility purpose.
4.	Publication of Technological / Process Manuals	01 number of standard operating procedure in the local Nyshi language was circulated among the farmers.	
	Others (if any)		

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
1.	Drying of Large cardamom	For reducing the carbon cost at IHR.	Commercialization is yet to be achieved.
2.	Grid-connected solar PV	Can enhance the livelihood due to augmented power supply.	Successfully implemented at project institute.
3.	Multi-layer farming	Awareness has been created	Farmers adopted the same.
4.	Conservation of ecology and particularly bumble bee.	Awareness has been created	Farmers adopted the same

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	1	Appropriate tools and techniques of farming		30		30
2.	On Field Training	31	3 prime objectives		233	107	233
3.	Skill Development	2	Project site farmers.		10		10
4.	Academic Supports	15 PG + 04 Ph.D.=19	PG and Ph. D. scholars report writing.		9	10	19

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held		Beneficiaries
1.	Sustainable Development Goal (SDG)	SDG-7 SDG -8 SDG-13	Publications 04 05 02	Events 02 23 08	100
2.	Climate Change/INDC targets	Climate resilient	04	02	100
3.	International Commitments	Paris climate agreement	04	02	100
4.	Bilateral engagements				
5.	National Policies	Skill India Mission Make in India Start-up India Deen Dayal Upadhayaya Swalamban Yojona		23	100
6.	Others collaborations				

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	Gaon Burah (Village head) helped to mobilize people.	Formation of Multipurpose cooperative society Ltd
2.	Govt Departments	Inputs regarding the official	Helpful in policy formulation

	(Agriculture/ Forest)	database.	and writing of research papers.
3.	Villagers	For assimilation of present knowledge and participative.	Formation of Multipurpose cooperative society Ltd
4.	SC Community	Not applicable	
5.	ST Community	Attended various workshops.	Helped in green livelihood.
6.	Women Group	Participated in survey, training need assessment, and workshop.	Designing of customised workshop based on project objectives.
	Others (if any)		

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	396000	490426	123.84
II.	Travel	200000	146243	73.12
III.	Expendables &Consumables	Nil	NA	NA
IV.	Contingencies	50000	45000	90
V.	Activities & Other Project cost	500000	148400	29.68
VI.	Institutional Charges	Nil	NA	NA
VII.	Equipments	800000	678331	84
	Total	1946000	1502069	
	Interest earned	79664		
	Grand Total	2025664		

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

9. Major Equipment/ Peripherals Procured under the Project** (if any)

S. No.	Name of Equipment	Cost (INR)	Utilisation of the Equipment after project
1.	Solar energy park	422000	For student demonstration.
2.	Electric Dryer (Commercial type)	256331	For student demonstration & power supply through grid.

Details should be provided in details **(*ref* Annexure III &IV).

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*01*	*Arunachal Pradesh.*
2.	Project Site/ Field Stations Developed	*01*	*Energy park at NERIST.*
3.	New Methods/ Modeling Developed	*01*	*Drying of large cardamom.*
4.	No. of Trainings arranged	*02*	*Based on project objectives*
5.	No of beneficiaries attended trainings	*233*	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*19*	*15 PG dissertations + O4 Ph.D.*
7.	SC stakeholders benefited		
8.	ST stakeholders benefited	*233*	
9.	Women Empowered	*100*	
10.	No of Workshops Arranged along with level of participation	*31*	
11.	On field Demonstration Models initiated		
12.	Livelihood Options promoted		
13.	Technical/ Training Manuals prepared	*01*	*Standard operating procedure.*
14.	Processing Units established	*01*	*Energy park and electric dryer.*
15.	No of Species Collected	*Nil*	
16.	New Species identified	*Nil*	
17.	New Database generated (Types):	*Nil*	
	Others (if any)		

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:		3	05	
2.	Book Chapter(s)/ Books:				

S. No.	Publication/ Knowledge Products	Number		Total Impact Factor	Remarks/ Enclosures
		National	International		
3.	Technical Reports				
4.	Training Manual (Skill Development/ Capacity Building)				
5.	Papers presented in Conferences/Seminars		6	2	
6.	Policy Drafts/Papers				
7.	Others:				

12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings	It would augment the green augmented economy in the inaccessible tribal areas. The self-sustainable farmers cooperative will attain the various SDGs.
Replicability of Project	The same process can also be implemented in the other mountainous region where the popularise of niche crop like large cardamom will boost the economy. The small cottage industry can be developed with support from the renewable energy.
Exit Strategy	The farmers' cooperative has collaborated with the state government to facilitate new farming packaged honey and eco-tourism in their village. It boosts the morale of the villagers for staying in the village, instead of migrating to the nearby cities.

(PROJECT PROPONENT/ COORDINATOR)

(Signed and Stamped)

01.12.2022

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Place: Nirjuli

Date: 01.12.2022

PART B: PROJECT DETAILED REPORT

1 EXECUTIVE SUMMARY

Large cardamom is a major cash crop for the Mengio circle of district Papumpare, Arunachal Pradesh. Cardamom farming has been popular amongst all the inhabitants of the region within a span of six years. The farming activities are not very labor intensive, hence most of the activities carried out by the woman. However, due to the ignorance of the farmers, non-formalized marketing network, less coordination amongst the farmers, they are not able to harness the proper value of the cardamom. Ultimately, the farmers sell these products to the intermediary at a very nominal price. Though they cultivate with very less chemical usage, still they are not able to receive the proper price for 'organic farming'. Informal marketing strategies, improper storing, and packing facility create constraints for the farmers of this region. Further, owing to insufficient transportation linkage, improper production and marketing knowledge regarding cardamom as a result, farmers compromise on price while selling products to local intermediaries.

The project is important due to many reasons, such as:

(1) The concept of cooperative may sound sporadic and new to these people, but for many centuries community based drove had led these people to overcome any obstacles for many generations. Perchance it is about indigenous methods such as RonghoRey(group farming) of Nyishi tribe, etc explicitly exhibited the cohesive and cooperative nature among these communities to comes together for common causes[1].

(2) The accessibility of knowledge regarding production and marketing of cardamom often create a hindrance for the marginal farmers of Arunachal Pradesh in general and Mengio circle in particular [7], [8].

(3) The traditional practices involve intermediaries to compromise with the price of the product yielding with less profit. The prevailing business environment offers lower profit due to the non-availability of market will demoralize the confidence of the local cardamom growers of this region. So a breakthrough in terms of marketing, production practices of cardamom is needed for the financial livelihood, and a self-esteem amongst the local people of this Himalayan region [9].

(4) The indigenous people of Indian Himalayan Region (IHR) has been engaged in traditional farming practices for many years for their livelihood. The definition of livelihood has been redefined by the need new generation. Hence, they have started adopting cultivation of cash crop like large cardamom (Amomum subulatum Roxb), kiwi, sandal wood, large cardamom due to its lucrative revenue option. However, adopting standalone cultivation of large cardamom becomes matter of risky. Scientific multi-cropping along with large cardamom cultivation has become widely recommended for this locality. This paper attempts to highlight intervention of Human Resource

(HR) capacity building (CB) in multi-cropping along with large cardamom for SL in the said region [1],[6].

(5) NER of India is known for its bio-diversity, the cardamom growers due to lack of awareness, and affordability prefer the short term benefit over the long run eco-conservation of the region[10]. For instance, the local inhabitants often cut down trees for site selection of cardamom growing, again for drying they undergo with wood charcoal.

(6) The scientific farming (cultivation and post-harvesting treatment) along with proper packaging and promotion would create many opportunities for the marginal farmers of IHR. The project would improve the socio-economic condition of the marginal cardamom farmers, along with balancing the ecosystem of the region. It will also involve eco-tourism through site visit.

(7) Besides, the proposed scheme is “by the people, for the people”, it will generate employment for the villagers [11], [12].

Objective-wise Major achievements of the project are as follows

1. Profitability augmentation for the marginal farmers
    - 03 workshop with the theme of “roadmap for livelihood” was organized.
    - 03 “workshop on cooperative farming society for the nearby cluster villages”, and
    - 07 “workshop on regulatory framework of cooperative farming society” were organized.
    - Registration of a total of 100 farmers under the Paniar Multipurpose cooperative society Ltd and selling of products under the farmers’ cooperative society banner for the financial year 2022 at a commercial scale.
2. Socio-economic development & incorporation of entrepreneurial skill sets
    - 05 workshops on “Awareness on Indian standards relevant to agriculture and food department”,
    - 05 workshops on “entrepreneurship development program on in large cardamom and other multilayer farming”,
    - NMHS sponsored a National seminar on tribal empowerment through the entrepreneurship of indigenous produced products -2019, May 9-10, 2019 at NERIST in collaboration with Tezpur University, and the Northeast regional centre of Govind Ballabh Pant 'National Institute of Himalayan Environment(NIHE).
3. Creating importance of environmental awareness through sustainable farming
    - 08 workshop on climate-resilient agricultural practices” were carried out.

Outputs in terms of Quantifiable Deliverables

1. Augmenting green source of income for the lower income group by large cardamom farming in 3 villages

Solar energy park demonstration to 30 farmers from 5 different villages of Mengio circle of Arunachal Pradesh leading towards Alternate source of green energy for livelihood at affordable price. Exposure to electric drying process 30 number of farmers from 5 different villages of Mengio circle of Arunachal Pradesh that leads towards reducing carbon emission by cutting and burning of trees.

2.Development of entrepreneurial skill sets amongst the 30 local inhabitants

A village-level committee was formed and a total of 10 Nos. individuals were selected as coordinators at the village level, and Training of Trainers (ToT) conducted that helped to achieve Paniar Multipurpose cooperative society Ltd and selling of products under the farmers' cooperative society banner for the financial year 2022 at a commercial scale.

3. Developing role model for other collaborative farming practices.

15 number PG dissertations submitted, 04 number of Ph.D at the final stage of process, Journal publications: 03 numbers (01 SCI + 01 Scopus + 01 Web of science). International Conference Proceedings (04 Scopus + 02 SSRN).

Linkages with Regional & National Priorities have also been achieved by addressing SDG-7, SDG -8, SDG-13. It also addressed national policies like Skill India Mission, Make in India, Start-up India, and Deen Dayal Upadhayaya Swalamban Yojona.

Briefs about partners of the project

G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Itanagar, Arunachal Pradesh.

- Knowledge partner in sharing his expertise of knowledge infusion.
- Logistic Support, Laboratory Facility,
- To provide test site for field-testing of the project, etc.

Department of Food Engineering and Technology, Tezpur University, Assam.

- Rendering their service in the post harvesting stage of the cardamom laboratory Facility
- To provide test site for field testing of the project, etc.

2 INTRODUCTION

2.1 Background of the Project

Sustainable livelihood (SL) development in the bio-diversity north eastern region (NER) of India has always been a great challenge [1]. Neither central government nor do the state government agencies have the elucidation to overcome such problems. To eradicate poverty, locally favourable cardamom farming along with multi-layer agriculture can be a suitable option [2]. Availability of new technique would help to overcome problems faced by the growers are the preparation and surveying of sites for cardamom in the Mengio circle of Arunachal Pradesh [3]. In Mengio, there is insufficient transportation linkage, improper production and marketing knowledge regarding cardamom as a result, farmers compromise on price while selling products to local intermediaries. For long duration storage of cardamom, and in order to bring out its aroma, the fresh cardamom has to be dried immediately after harvesting to bring down its moisture content from 80% initial moisture content to 10% moisture content through drying [4]. Still primitive and inefficient methods are being used for drying of cardamom, which results in poor quality product. Therefore, renewable energy efficient drying process has to be designed for yielding a better quality product in terms of color, flavor, and percentage yield of oleoresin extract [5]. It will also be helpful to encourage locally cultivated multi-layer plantation of Aloe Vera, Cinnamon, black pepper, and Citronella. It will also encourage eco-tourism through site visit [6]. All these defined problems can be easily and economically addressed through the proposed project.

2.2 Overview of the Major Issues to be Addressed

The project is important due to many reasons, such as:

(8) The concept of cooperative may sound sporadic and new to these people, but for many centuries community based drove had led these people to overcome any obstacles for many generations. Perchance it is about indigenous methods such as RonghoRey(group farming) of Nyishi tribe, etc explicitly exhibited the cohesive and cooperative nature among these communities to comes together for common causes[1].

(9) The accessibility of knowledge regarding production and marketing of cardamom often create a hindrance for the marginal farmers of Arunachal Pradesh in general and Mengio circle in particular [7], [8].

(10) The traditional practices involve intermediaries to compromise with the price of the product yielding with less profit. The prevailing business environment offers lower profit due to the non-availability of market will demoralize the confidence of the local cardamom growers of this region. So a breakthrough in terms of marketing, production practices of cardamom is needed for the financial livelihood, and a self-esteem amongst the local people of this Himalayan region [9].

(11) The indigenous people of Indian Himalayan Region (IHR) has been engaged in traditional farming practices for many years for their livelihood. The definition of livelihood has been

redefined by the need new generation. Hence, they have started adopting cultivation of cash crop like large cardamom (Amomum subulatum Roxb), kiwi, sandal wood, large cardamom due to its lucrative revenue option. However, adopting standalone cultivation of large cardamom becomes matter of risky. Scientific multi-cropping along with large cardamom cultivation has become widely recommended for this locality. This paper attempts to highlight intervention of Human Resource (HR) capacity building (CB) in multi-cropping along with large cardamom for SL in the said region [1],[6].

(12) NER of India is known for its bio-diversity, the cardamom growers due to lack of awareness, and affordability prefer the short term benefit over the long run eco-conservation of the region[10]. For instance, the local inhabitants often cut down trees for site selection of cardamom growing, again for drying they undergo with wood charcoal.

(13) The scientific farming (cultivation and post-harvesting treatment) along with proper packaging and promotion would create many opportunities for the marginal farmers of IHR. The project would improve the socio-economic condition of the marginal cardamom farmers, along with balancing the ecosystem of the region. It will also involve eco-tourism through site visit.

(14) Besides, the proposed scheme is “by the people, for the people”, it will generate employment for the villagers [11], [12].

2.3 Baseline Data and Project Scope

The baseline data for this project like the livelihood and practices of many agricultural and horticultural product has carried out several post-graduation dissertation works. Two dissertations have addressed cardamom farming in the Mengio circle of Arunachal Pradesh. As per the Paris agreement, India has volunteered to take the pledge towards maintaining the balance in the ecosystem through new plantations and to find out an innovative way to reduce carbon costs. Programs of this project target to achieve the same in long term in various manner. The concept of community cohesion has never been put on the right track toward cooperative farming practices for commercialization of farm produce production at any level. The idiosyncratic farm management system has its own difficulties [1]. For instance, lack of financial aid for both on-farm and off-farm inputs, road connectivity, logistic, warehouse, cold-storage facilities for perishable farm production, and very less exposure to market linkages. Today with steady development of infrastructure and economic upliftment the major population has felt the importance of agriculture activities as not only for self-consumption in addition to it, the commercialization of surplus production markets for augmentation of income for SL. The problems associated with an idiosyncratic approach can be mitigated through the formation of farmers’ cooperative. The farmers’ cooperative society (FCS) or pooling of people and resources for the common interest will help the individual to come together and aggregate the production at large quantity which will further help the farmers to supply the

product at large quantity with more bargaining power towards buyers. The conventional/traditional practices of farming and producing and solely managing the entire process from sowing to selling the surplus product into the market are involved with higher production costs, in addition to that, low profits with lesser freedom to bargaining power as individual farmers. This project generally highlighting the benefits of working as groups in the arena of farming in the interest of commercializing of farming activities in a broader perspective for more viable, sound livelihood option for a living [1], [6].

The project would conserve the forest of the bio-diversified Mengio circle of Arunachal Pradesh located in the NER. It will also involve eco-tourism through a site visit. Besides, it would also focus on the livelihood of the marginal farmers, and simultaneously it will promote gender equity through cardamom farming in scientific green procedures. The beneficiaries include the marginal cardamom growers of the Mengio circle of Arunachal Pradesh. As the ratio of woman farming in cardamom is significant, hence it would also cater benefit to the woman of the region.

The scope of the project includes:

(1) It will provide supplementary livelihood options for the remote rural inhabitants in this region.

(2) It will help in enhancing the CB of the rural IHR.

(3) It will provide sustainable infrastructure development and will enhance the energy security.

2.4 Project Objectives and Target Deliverables

The project aim intends to analyze demographic, cultural factors, and purchasing options that influence the consumption of cardamom produced in Arunachal Pradesh. Further, based on the forecasting, the project aims at finding out time, capital, and need-based technology, as well as workforce planning for eco-friendly scientific high yield farming [13], [14] as well as the marketing of cardamom in Mengio circle of Arunachal Pradesh. The project will act as a helping guide the start-ups related to other agricultural products in Arunachal Pradesh.

Objectives of the project includes:

1. Profitability augmentation for the marginal farmers of the Mengio circle of the Arunachal Pradesh.
2. Socio-economic development of the region through incorporation of entrepreneurial skill sets amongst the local inhabitants.
3. Creating importance of environmental awareness through sustainable farming.

3 METHODOLOGIES, STARTEGY AND APPROACH

3.1 Methodologies used for the study

The selection of the group of villagers was done through convenience sampling, as ongoing collaboration between the villagers of Mengio circle of Arunachal Pradesh and the project staffs resulted in cooperation in carrying out the convenience sampling. Through the convenience Sampling method eight sample remote villages namely: Sakiang, Pan, Old Mengio, Kullung, Pacho, Nyopang, Paga, and Heyang were selected. More than twenty numbers farmers were then interviewed by the project staff after the assignment on training need assessment was completed. The data from the diaries and interviews was analyzed using constructivist grounded analysis [15]. Data was collected from villagers in the form of a structured diary which asked marginal farmers to comment on a range of aspects of their use of agriculture literacy skills during their training need assessment process. The diary also asked marginal farmers to comment on their levels of confidence at different stages of the large cardamom-based agribusiness process and asked them to evaluate the quality of their assignment and how they might have improved it.

The second stage of data collection took the form of semi-structured interviews of the marginal farmers who were completing the training need assessment assignment. Interviews are recommended as a source of rich data recommends that 'intensive interviews' should be used in grounded theory studies to provide depth. In interpreting interviews, constructivist researchers recognize that, as with the diaries mentioned above, interviews are the participants' construction of what they view as reality; it was the researcher's task to interpret what participants say (and sometimes what they do not say) in order to construct the researcher's view of the studied world [15].

3.2 Preparatory Actions and Agencies Involved

Training need assessment was carried out in the initial interactions by the focus group interactions with the villagers to achieve the targeted three objectives. Each objective was prepared with the outline approach to achieve as the output by collecting need assessment and followed by organizing various outbound activities and in house training. More focus was given on the outbound workshops keeping the convenience of the farmers as well as the cost reduction of the project. The three objectives were planned with certain theme based workshops that were organized in the villages. As the population density is very low, sometime more than one villages were also combined together for disseminating the awareness level amongst the farmers.

Training need assessment was carried out in the initial interactions by the focus group interactions with Indigenous practices involved in cardamom farming, agro farming and marketing were carried out by Micro-entrepreneur of Arunachal Pradesh.

Table 1: Briefs about partners of the project

S.N	Project Partners	Support
1.	G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Itanagar, Arunachal Pradesh.	**1.** Knowledge partner in sharing his expertise of knowledge infusion.**2.** Logistic Support, Laboratory Facility, To provide test site for field-testing of the project, etc.
2.	Department of Food Engineering and Technology, Tezpur University, Assam.	**1.** Rendering their service in the post harvesting stage of the cardamom laboratory Facility To provide test site for field testing of the project, etc.

Besides the above project partners, the project team consulted the following agencies for different objectives.

For Livelihood, socio-economic development of the project site we consulted:

- National Bank For Agriculture And Rural Development (NABARD) officials.
- Arunachal state livelihood mission (ArSLM)

Regarding the marketing, economic value addition of the large cardamom, the following stakeholders were consulted on the regular intervals:

- Indian Cardamom Research Centre, Gangtok, Sikkim.
- Spice board of Itanagar and Ziro of Arunachal Pradesh.
- Inspection of Electric Dryer installed by progressive local entrepreneur.

Similarly, for benefits of the farming aid of the local farmers, we consulted

- Horticulture officer of Arunachal Pradesh.

3.3 Details of Scientific data collected and Equipment Used

The basis of the project was to offer a livelihood with the help of green technology. To achieve this objective we have selected the source of energy to be affordable as well as to be technologically feasible for installation at the project site by the farmers after the completion of the project. Green sources of energy could be achieved in various ways like solar Photo Voltaic (PV), wind, biogas, and micro hydel. Based on the economic feasibility, and climatic conditions the project team has decided to adopt solar PV based electrification [17], [18]. To check the average insolation levels available in the proposed site HOMER-Pro software using a satellite database was used. As

presented in the fig.2, average insolation levels are found suitable for the installation of solar PV at the project site [16].

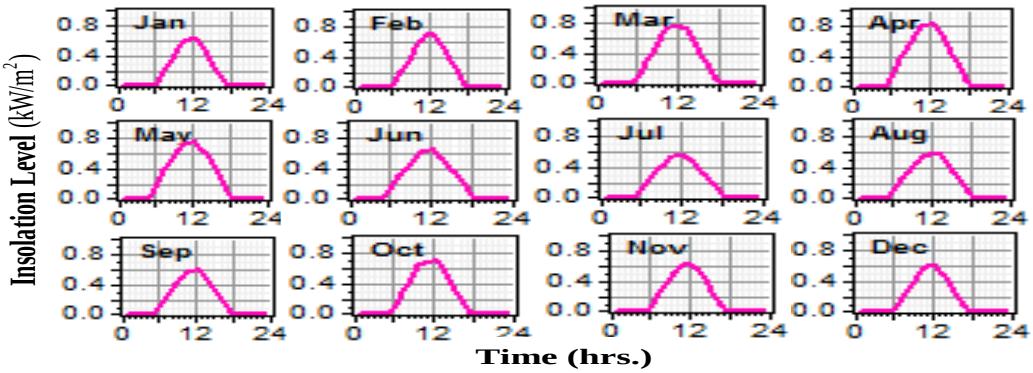


Figure 1: Average insolation levels available in the proposed site
(Captured through HOMER-Pro software using satellite database)

Hence a prototype solar PV energy park of it was developed at our institute premises with grid connectivity electricity supply. The developed prototype energy park was also visited by the beneficiaries.

3.4 Primary Data Collected

The research work is qualitative in nature comprising primary and secondary data. Primary data were collected through structured questionnaire vide personal interviews and personal observation for data validation. Whereas secondary data were collected from different sources of annual reports of government of India: ministry of small and medium enterprises (MSME), Census India, 2011, North Eastern Council (NEC) Secretariat, Mission for Integrated Development of Horticulture, Government of India, business news, books, Spice board journal, Ministry of Rural Development etc. For this study here the combination of judgement and convenient sampling were used. The sample size for this study included villages of Mengio circle of Arunachal Pradesh. No connected examination has been carried out in this region, till this date. Accordingly, the "Theory Building" idea has been utilized for proposing the model, of this project. Theory building [15], is a broadly utilized idea in research territories, as it gives an examination structure to the investigation, additionally a proficient field improvement should be possible utilizing this idea and also it helps in further applicability for solving the problems and issues related to the practical real world. Theory, however a dreary artistic expression, practical, without theory, can be hazardous and dull. In explanatory reasonable examination, a subcategory of "theory building" idea, adds new bits of knowledge into conventional issues through logical relationship building. So in this project, we utilized the "theory Building" concept, along with primary and secondary data, for the study.

3.5 Details of Field Survey arranged

For profitability augmentation of the marginal farmers of the Mengio circle of Arunachal Pradesh following 13 workshops were conducted at their respective village:

- 03 workshop with the theme of “roadmap for livelihood” was organized.
- 03 “workshop on cooperative farming society for the nearby cluster villages”, and
- 07 “workshop on regulatory framework of cooperative farming society” were organized.

For the second objective related to the socio-economic development of the region through the incorporation of entrepreneurial skill sets amongst the local inhabitants by organizing 10 workshops at their village were conducted

- 05 workshops on “Awareness on Indian standards relevant to agriculture and food department”,
- 05 “entrepreneurship development program on in large cardamom and other multilayer farming”,

Finally, the objective on creating importance of environmental awareness through sustainable farming by organizing

- 08 “workshop on climate-resilient agricultural practices” were carried out.

Similarly, 01 number of workshop and 02 exposure trips were organized for the marginal farmers of the Mengio circle. 01 training of trainers was also conducted in the institute premises.

3.6 Strategic Planning for each Activities

For profitability augmentation of the marginal farmers of the Mengio circle of Arunachal Pradesh following several workshops and awareness camps were conducted at their different villages of Mengio circle of Arunachal Pradesh like Sakiang, Pan, Old Mengio, Kullung, Pacho, Nyopang, Paga, and Heyang. The multi-cropping, and multi layer practice along with CB with the large cardamom has been considered to be the focal point for the livelihood of the people. It needs community-based scientific optimal resource allocation from the point of long run sustainability. Community farming in this locality has been practised by the farmers in their indigenous manner. However, modern day community farming aims at increasing the different dimensions of farming. The country-wide community based farming can be beneficial for modern technological CB. Initially, a Training Need assessment was organized in these villages. Accordingly, the roadmap for livelihood, workshop on FCS for the nearby cluster villages, and workshop on the regulatory framework of FCS were planned.

The second objective related to the socio-economic development of the region through the incorporation of entrepreneurial skill sets amongst the local inhabitants by organizing workshops in their village was conducted related to workshops on awareness of Indian standards relevant to agriculture and food department, and entrepreneurship development programs for large cardamom and other multilayer farming were organized. The CB for manpower development through the intervention of different outsourced agencies has also been observed in recent research work in both developing and underdeveloped economies. Further, the traditional farming techniques have also been redefined by the intervention of CB and value chain mapping. The project discusses the need of HR capacity intervention through a case study by exposure trips to a local progressive farmer was organized. Training of trainers was also conducted on the institute premises.

Finally, the objective of creating important environmental awareness through sustainable farming by organizing workshops on climate-resilient agricultural practices was carried out.

3.7 Activity wise Time frame followed [using Gantt/ PERT Chart

Activity wise time frame followed is shown in fig.2 and presented as follows:

1. A preliminary survey has been conducted based on the three objectives of the project.
    a. Hence, to advance an understanding of how renewable energy augmented mountain economy can be achieved, this project conducted a systematic literature review. The search string (“livelihood”, “human capacity development”) AND “Renewable Energy” AND “sustainable rural development” was entered into various databases (google scholar, Science Direct, Elsevier, Taylor and Frances, Willey online library, etc.) for title, abstract and keywords. The term “sustainable mountain development” was chosen as it covers a wide perspective for the search. The search was conducted from 2015. Including only articles published in the journal from 2015 onwards and removing duplicates, book chapters, and monographs. The focus on an impact factor of more than 2 (ranging between 2-18), was achieved by removing articles published in different journals.
    b. First of all, personnel of the project implementing partners like: GBPNIHESD, Itanagar, Arunachal Pradesh (Pic 7), and Department of Food Engineering and Technology, Tezpur University was consulted to carry out the process plan. Similarly, for the local knowledge input different stakeholders like large cardamom farmers of the region. The processed large cardamom often faces problems due to individual farmers’ involvement with the complete value chain. So it was decided to constitute a FCS of the project site, so inputs in this regard were collected from the officials of ArSLM, Itanagar (Pic1), Assistant Registrar, Cooperative Society of Arunachal Pradesh (Pic 5) were collected. Further, to know the scope of financing different institutions like NABARD, Itanagar (Pic 2), and bank officials of North East Small Finance Bank (Pic 6) were also consulted. To augment the marketing

process the agencies like the Agricultural and processed food products export development authority (APEDA), and Arunachal Pradesh agriculture marketing board (APAMB) were consulted.

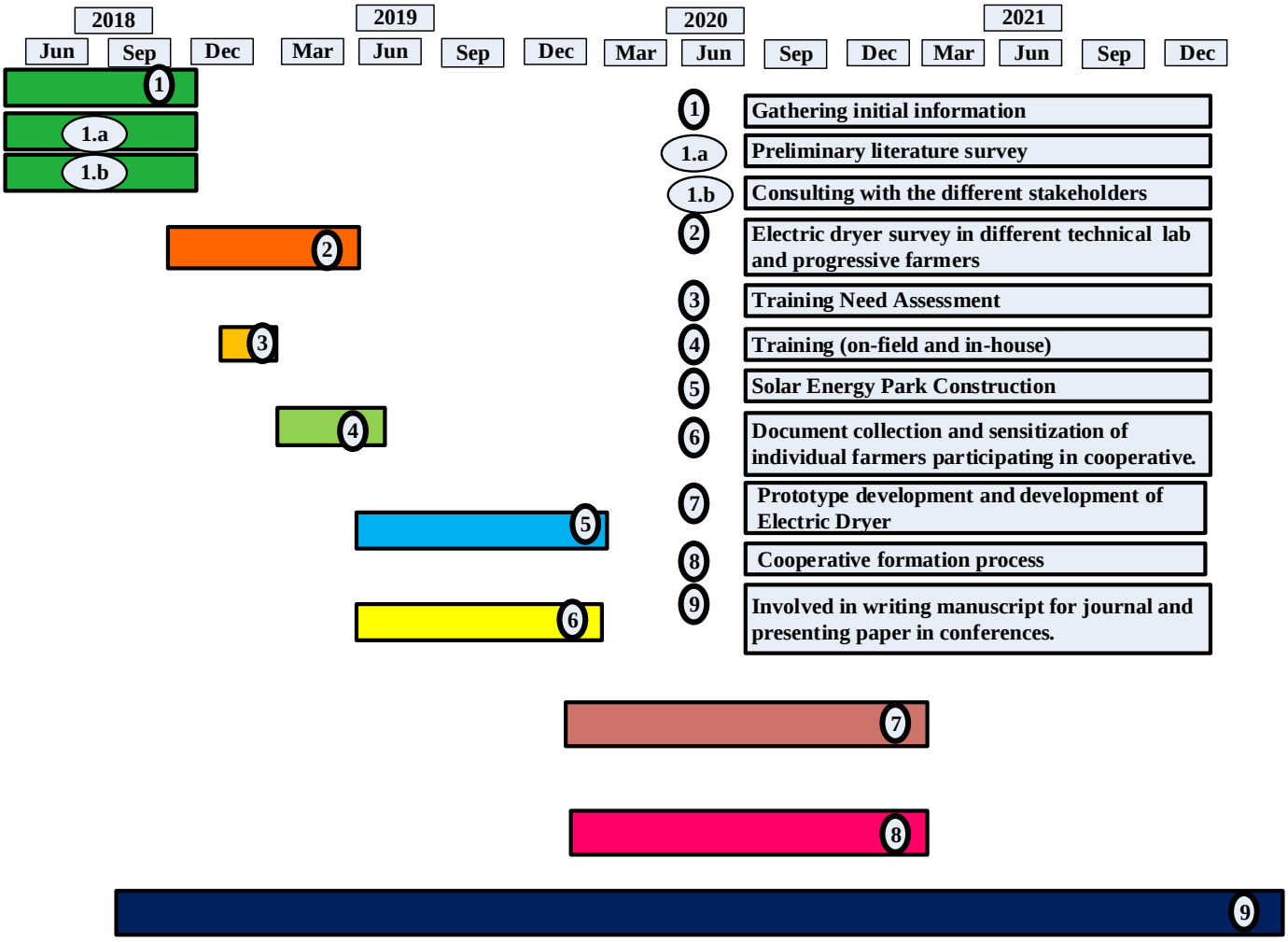


Figure 2: Activity wise time frame of the project

2. The major challenge of large cardamom lies with the drying process, hence traditional large cardamom dryers by the local farmers (Pic 10, Pic 12) were visited. An exposure visit to a dryer installed by the department of horticulture at project site under Rashtriya Krishi Vikas Yojana (RKVY) (Pic 9) and an inspection of an electric dryer installed by a local progressive entrepreneur (Pic 11) was also conducted during the said period. Then consulted with the officials of Spice Board of Itanagar, and Ziro of Arunachal Pradesh (Pic 3) to know the real issues of the cardamom drying. Further the project team also visited the Indian Cardamom Research Centre, Gangtok, Sikkim (Pic 4, & Pic 8) for further knowledge inputs on the same.
3. Initially, a training need assessment (TNA) was organized in the villages of Mengio circle of Arunachal Pradesh like Sakiang, Pan, Old Mengio, Kullung, Pacho, Nyopang, Paga, and Heyang. The TNA was conducted in alignment with the three objectives of the project (Pic 23).

4. For profitability augmentation of the marginal farmers, 13 workshops were conducted at their respective villages with themes like livelihood planning, FCS for the nearby cluster villages, and regulatory framework of FCS was organized. The second objective of socio-economic development was achieved by organizing 10 workshops in their village were conducted related to the topic of Indian standards relevant to agriculture and food department, and entrepreneurship development programs in large cardamom and other multilayer farming [19]. Finally, the objective of creating the importance of environmental awareness through sustainable farming by organizing 08 workshops on climate-resilient agricultural practices was carried out (Pic 13, Pic 14) . 01 number of conference cum workshops (Pic 21) and 02 exposure trips (Pic 22) were organized for the marginal farmers of the Mengio circle. 01 training of trainers (Pic 17) was also conducted in the institute premises.
5. A prototype 5kW solar power plant was developed at our institute premises with grid connectivity electricity supply. The developed prototype energy park was also visited by the beneficiaries (Pic 20).
6. The JPF during the period of pandemic has contacted the farmers to sensitize them to form a FCS. Afterward, all the required documents like aadhar card, and other requisite were also collected from the farmers based on the suggestions of the assistant registrar of the cooperative society.
7. The prototype for the large cardamom drying was prepared by the Co-PI in consultation with the personnel of the project implementing partners like: GBPNIHESD, Itanagar, Arunachal Pradesh, and Department of Food Engineering and Technology, Tezpur University.
8. To increase the financial capacity of local farmers, while prioritising the pooling of fund, and accessing group guarantees for availing bank loans, a farmer's multipurpose cooperative society was formed under the Name of Paniar Multipurpose cooperative society Ltd (PMCSL) (Pic 15, Pic 16, Pic 18, Pic 19).
9. Simultaneously there were also knowledge database created by the project simultaneously since the beginning of the project work like 15 number PG dissertations submitted, 04 Ph.D. at the final stage of the process, Journal publications: 03 numbers (01 SCI + 01 Scopus + 01 Web of science), International Conference Proceedings (04 Scopus + 02 SSRN).

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings

Drying of cardamom is a relatively sophisticated process and requires considerable energy consumption. The inability to adequately dry the produce will lead to mould growth. Any cardamom with even a trace of mould cannot be used for processing. The sale value of mouldy cardamom can be less than 50% the normal value. Green dried cardamom receives a premium in West Asia and hence drying has to be done in such a way as to preserve the green colour. The drying temperature should not exceed 50°C and the

drying process should be an energy efficient process. Fossil fuel carriers commonly supply the energy requirement for dryers, which are mostly hot air dryers. The global increase in demand for fossil fuels and the consequent increase in their prices, the insecurity of their resources, and environmental concerns have resulted in increasing interest in using renewable energies, such as solar power, as alternatives to fossil fuels [4]. Hence, solar power systems have been widely considered and developed. Due to the recovery of waste heat in heat pump systems, they reduce energy consumption and thereby provide efficient and environmental friendly technologies. Heat pump dryers are highly energy efficient and are most suitable for heat-sensitive product such as cardamom. Therefore, in the present project, the performance of a solar assisted heat pump drying system was used for cardamom drying, in order to obtain a high-quality product. The effect of air mass flow rate at different levels, drying air temperature and two different solar assisted dryer modes i.e. without the heat pump unit (Double-pass solar collector solar drying) and with heat pump unit (Solar assisted heat pump dryer) on the operating parameters of the dryer on economy and product quality was studied. Double-pass solar collector solar drying: The main components were: Solar collector array, Auxiliary heater, Blower, and Drying chamber.

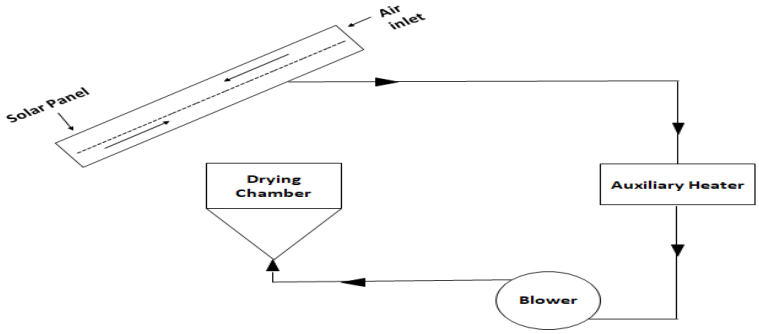


Figure 3: Schematic of the solar drying system with double pass collector

Solar assisted heat pump drying system: the principal advantages of heat pump dryer were its ability of the heat pumps to recover energy from the exhaust and the ability to control the drying gas temperature and humidity. Solar assisted heat pump dryers produced a better quality product due to its ability to work at low temperatures [10]. This process had the ability to inactivate the enzymes that break down the chlorophyll and retain the pink color of the product.

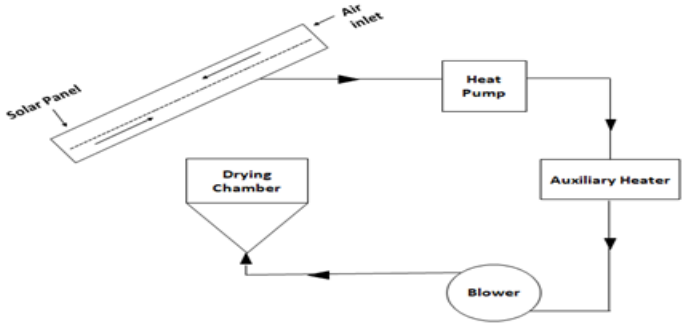


Figure 4: Schematic of the Solar assisted heat pump drying system

The system consists of four mean components solar collector, storage tank, Heat pump unit,and Dryer chamber. The drying chamber contains multiple trays to hold the drying material and expose it to the air flow. In this process the incoming air was heated and enters the dryer inlet at the drying condition and performs drying. After the drying process, part of the moist air stream leaving the drying chamber is diverted through the evaporator, where it was cooled. The air was then passing through the condenser where it is reheated and then sent to the drying chamber. The cardamom would be dried from average initial moisture content of 80% wb to an average final moisture content of 10% wb by this process [4], [10].

4.2 Key Results

The key results of the projects are to obtain a better aroma of the large cardamom by the solar dryer, which will facilitate minimization of bio resources, space management, and reduce the carbon cost. Besides, multilayer farming will also create opportunities for the green skill development through eco-tourism, other spices, medicinal plants, as well as woods during the trimming of shade plantations. The branding of the products, in the long run, will give financial independence to the FCS for further growth and expansions as shown in fig.5.

The detailed highlights are listed below:

- Black cardamom (Amomum subulatom Roxburgh) belongs to the family Zingiberaceae, and black cardamom is popular for its spice components. The black cardamom capsule contains phytochemicals that have anti-inflammatory and antibacterial properties. The essential oil obtained from the black cardamom has a distinctive characteristic fla- vor and has demonstrated several medicinal functions, including alexipharmic, stomachic, stimulant activities, and astringency [4]. Therefore, black cardamom has been utilized for treating stomach torments and digestion related disorders. The composition of cardamom varies with the corresponding cultivar and stage of development of the capsule. Similarly, the composition is also affected by the region of cultivation and the corresponding cli- mate of the region. The various components of the dried fruit of black cardamom include volatile oil (2.8–4.0%), protein (6%), starch (43%), ether (5%), and ash (4%). Cardamom seeds are consumed in various forms, such as whole or powdered forms. It is one of the most valuable spices employed as an ingredient of curry powder, sausages, desserts, cakes, confectioneries, and beverages, such as coffee and tea. Traditionally, cardamom curing was done using Bhatti, in which freshly harvested cardamom pods are dispersed on the drying plat- form and hot smokes produced from the firewood were passed through the layer of freshly harvested cardamom spread[10], [20], [21].

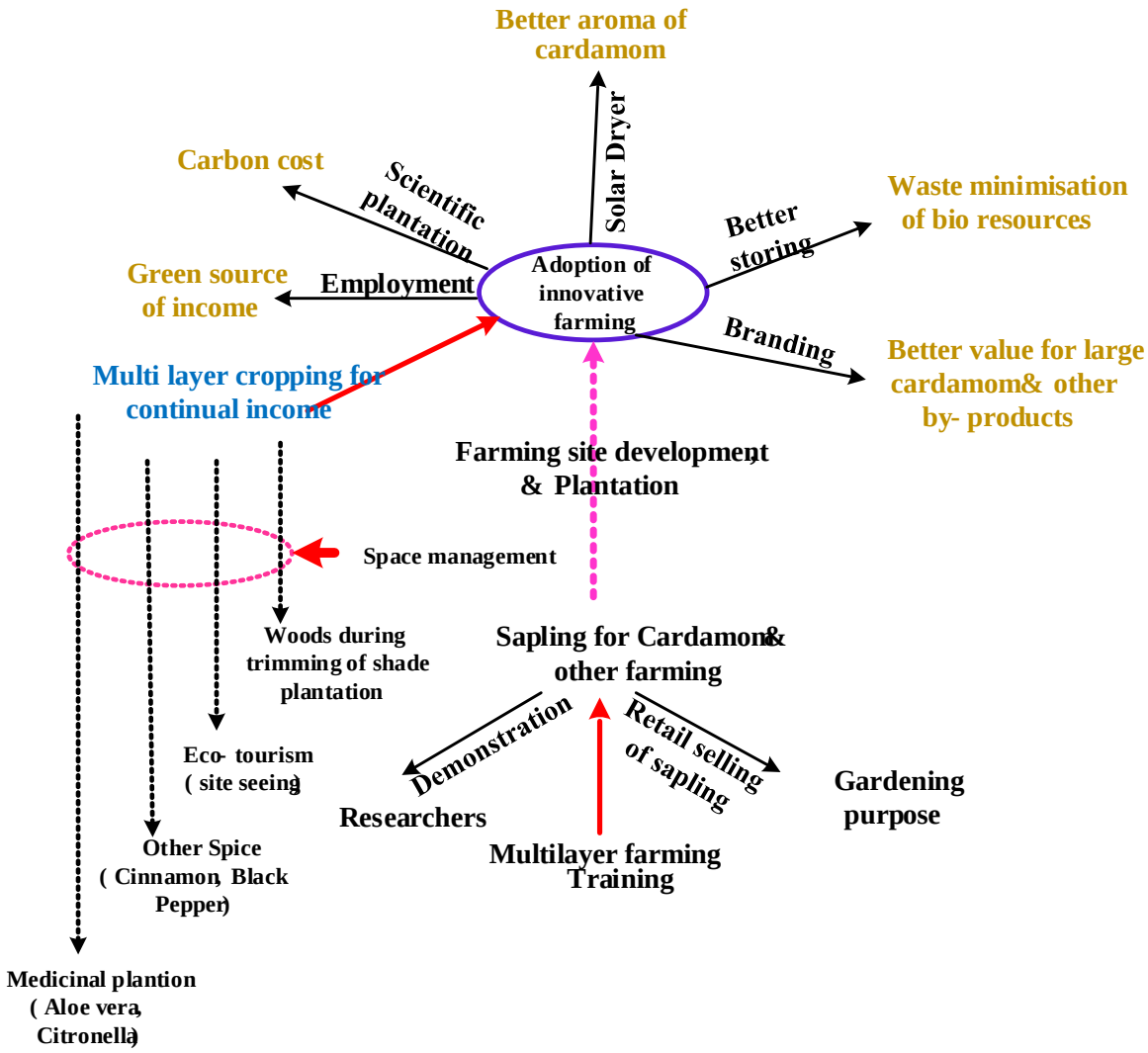


Figure 5: Key Results of the project-an illustration

However, in this case, constant attention is necessary to regulate temperature and maintain uniformity during drying. The fire produced during the traditional drying process is beyond control, leading to overheating, leading to a charred, smoky floured capsule with reduced volatile oil content. Generally, the conventional drying process can be as long as 48–72 hr and consume approximately 10 kg of firewood per 1 kg of dried black cardamom produced during the process. This reduces the final quality of volatile oil, rendering a low-quality product in the market. Hence, an alternate method of drying is essential for solving this problem. Among different renewable energy sources, including geothermal, solar, and biomass, solar energy can be exploited and utilized worldwide, as geothermal sources are available at few locations and the supply of biomass is limited. Hence, these resources are not practically conducive for the respective applications. The intensity of solar flux passing through the earth's atmosphere is determined by several features. Some of the important factors include regional climate, corresponding latitude,

geographic variation, and diurnal variation. Solar energy is one of the major potential alternatives for curbing the increasing demand for green energy. Drying using solar dryers is a modified version of the traditional sun drying technique, which has generally been employed to dry most agricultural commodities. In comparison to sunlight-based drying, solar dryer maintains higher air temperatures, and significantly lower relative humidity, and hence improved drying rates can be achieved. Different types of solar dryers, including direct dryers, indirect and hybrid dryers, have been used and optimized to achieve the best drying conditions targeted towards maximum overall performance of the system. The performance of the solar drying systems was investigated using the energy and exergy approaches in this project [10].

- However, modern day community farming aims at increasing different dimensions of the farming. The country-wide community based farming can be beneficial for the modern technological CB. The CB for manpower development through intervention of different outsourced agencies has also been observed in recent research work in both developing and underdeveloped economy [22], [23]. Further, the traditional farming techniques has also been redefined by the intervention of CB and value chain mapping. The paper discusses the need of HR capacity intervention through a case study with objectives: i) to analyze various and best combinations of multi-cropping along with large cardamom cultivation in the region for SL among the cultivators, as well as ii) streaming human resource intervention for CB for the same[19].
- It has been observed that this centuries-old indigenous practice has added a more competitive edge by focusing on FCS. On evaluation, this new modern concept of group farming with old beliefs and practices of community-based work pattern there is a similarity of team- work and the formation of groups and essence of a team led by leaders is somewhat shown the cohesive quality work by this community [24]. The FCS has excelled and reaped the benefits by joining as a member company with accessibility to micro/macro credits, loans, storage, drying facilities, and most important market linkage with more exercising of bargain power [25], [26]. The major challenges face by farmers create an environment of professionalism approach, as the FCS is formed by these members with the same common interest, farmers from no formal education unknown to the management proficiencies and practices [1].
- In this project, for rural cluster electrification and enhanced agricultural technology, information and communication technologies have been introduced to make agriculture more sustainable. Renewable energy systems are those that are not prone to degradation and use primary energy supplies. Examples of green energies [27], [28], [29] include solar, wind, geothermal, and biomass. Solar energy is the light that comes right from the Sun. It is the most concentrated source of energy on earth including nuclear weapons. PV cell, which transforms sunlight directly into electricity, is the fastest growing form of renewable energy, rising at 50 per cent a year. The Sun provides more than 10, 000 times the electricity actually consumed by humans per year. Different cost-effective approaches have been developed by various researchers using solar

power, wind power, hydroelectric power for use in various industrial sectors, technical institutions, and underdeveloped rural areas. The different energy sources, e.g. solar, wind, hydraulic, biomass, organic waste, biofuels, and combined heat and electricity, provide the electric generator with a simple, reliable and efficient solution.

In this project, it has been observed that the average solar radiation at the test site is well above the standard 0.2 (kWh/m2/day). This is the minimum radiation level above which it is suitable for solar PV power generation sites economically [30], [31]. Therefore, the site is found to be suitable for solar PV based on renewable power generation technologies. Based on a proposed 5kW solar power plant, the cost analysis has been performed in an attempt to compute the cost of energy. The estimated cost is found to be $0.1756/- which is significantly less than the present cost of energy from conventional sources at the same location [16].

4.3 Conclusion of the study

- As many actives, of machine nature, are currently being done manually [32]. This leads to high cost, time-consuming and resulting in low productivity, therefore, the paper focus on achieving a cooperative sustainable farming system by adopting green energy sources[33], [34]. Renewable energy based electric dryer was developed and proposed in this project., the technical based FCS model, if implement properly can result in various benefits such as providing a platform for communication with the outer world, systematic and structured working pattern where each one gets a clear idea about the work, increased production, economic development of farmers, market linkage, optimal utilization of land, organized source of employment, bulk surplus, being a FCS, high valued machinery can be purchased, etc. the benefits are enormous [35], [36].

- This project has analyzed systematically the present agricultural practices [36], [37] in Mengio circle of Arunachal Pradesh, India and successfully proposed a FCS based, technologically empowered farming model to improve the SL of the beneficiaries in the said region.

- Also, the project highlighted appropriately the benefits of FCS farming with reference to the farmers of Mengio circle of Arunachal Pradesh in particular and farmers in other regions in general. This system will not only increase the standard of living but also increase the feeling of friendship, cooperation and there by achieves a synergy in the agricultural sector.

- The study infers the importance of indigenous community based knowledge for improvising relation among different tribes. Besides, it can protect and preserve old beliefs and practices prevailing in the community. Lastly, it concludes the significant role played by many players ensuring the perseverance of indigenous community-based knowledge and practices with a blend of modern FCS. The similar success stories would build confidence among the ethnic group of the different region to participate in formalizing the agriculture sector.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives

- The socio-economic scenario and bio-diversity of the located site at the IHR of the project have been studied. The Nyishi community is the inhabitants of the project site. The Nyshi community of IHR has been recognized as one of the ethnic groups comprising of many sub-tribes of the same antecedent. Their old scientific management of natural resources through their indigenous belief and practice system. The traditional knowledge of the community, though has not been recorded in the writing format, has been preserved by passing the knowledge from one generation to another generation by word of mouth and daily need-based practices. The project highlights the inter-relationship between indigenous community-based beliefs and practicing cooperation and management of natural resources and farming practices for many centuries. preserve and scientific agroforestry approaches such as The Abotani community has also been involved in community management practices like Kebang, Kabo, Soru-Ruth, Rongo-Ray, Aka Mele, Buling. The project has emphasized the similarity with that of the present days village community management system and modern. Finally, the project has attempted to form commercially viable cooperative farming [1].
- Many studies have proved that the highest efficiency in farming can be achieved only by the means of electrical energy and hence technological intervention. Technological intervention in the area of agriculture will increase the competence of certain farming activities. Renewable energy can play a major role in agriculture and particularly in cooperative farming for sustainable growth. Moreover, the intervention of renewable energy in farming will not only help in rural development missions but also creates a sustainable environment for the entire world in terms of reduced carbon cost [38], [39]. Hence, in this project, the significance of the solar PV based renewable sources of energy in the corporative farming sector for the said location and its feasibility study has been studied and installed grid-connected 5kW solar PV based energy park at the North Eastern Regional Institute of Science and Technology (NERIST) institute. Some of the similar reviews done by various authors in their respective journals are:[40], in their study says that encouraging the use of electric power in the farm is a worthy effort, even though it is not possible to replace renewable energy with fossil fuel simply, leaving everything unchanged, but it is possible only utilizing more efficient use of energy and mineral resources, as well as an approach in a more respectable way to preserve soil and local resources.
- Free energy sources and sustainability are the benefits of this solar dryer system. Agricultural producers are considering the use of renewable energy, such as solar energy,

in the drying of agricultural goods. The design of the solar collector was based on the minimum entropy generation number. In this project, a dynamic model was provided in which the kinetics of moisture reduction are calculated based on the quantity of solar energy received in the collector and the temperature fluctuation in the collector. The exergy input and exergy loss of the dryer are affected by solar radiation. The quantity of energy received and consumed is included in the energy analysis [4].

- Further an electric dryer is also developed for the drying of large cardamom through indirect heating.

5.2 Establishing New Database/Appending new data over the Baseline Data

- Feasibility Study on Solar PV based Renewable Energy at the project Site: The Mengio is located in the IHR biodiversity region is situated in the global positioning of 28.15285° N, 94.12288° E. The average solar radiation *(kWh/m^2/day)* data has been collected for the year 2019 with a sample size of 7 samples/day basis using the Solar Radiation (Silicon Pyrometer) Smart Sensor - S-LIB-M003.

  The collected data has been shown in Fig.6. Figure-1: Average solar radiation in a year at 27.0016^{0}N, 94.2243^{0}E.

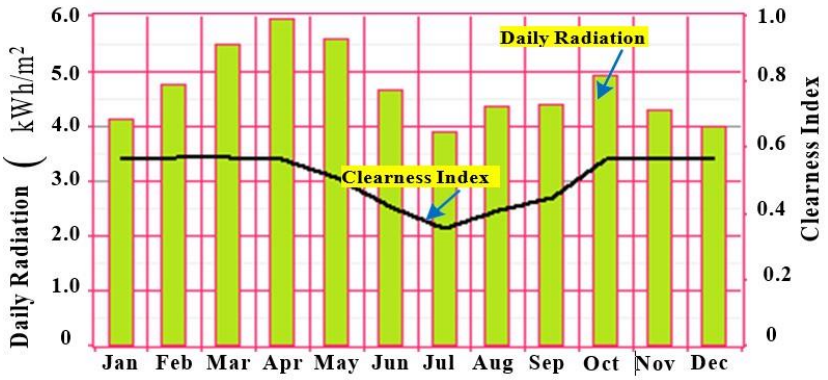


Figure 6: Average solar radiation in a year at the project site (27.0016^{0}N, 94.2243^{0}E)

It has been observed that the average solar radiation at the test site is well above the standard 0.2 (kWh/m^2/day). This is the minimum radiation level above which it is suitable for solar PV power generation site economically [32-35].

Therefore, the site is suitable for solar PV based on renewable power generation technologies. Based on a proposed 5kW solar power plant, the cost analysis has been performed in an attempt to compute the cost of energy as shown in Table-2. The estimated cost is found to be $0.1756/- which is significantly less than the present cost of energy from conventional sources at the same location [16].

Table 2: Cost of energy with proposed 5kW solar PV power plant

Cost Factors	Value
Initial Capital Investment ($)	6600/-
Cost of Energy ($/kWh)	0.1756/-
Net Present Cost ($)	1220/-
Operating Cost ($/year)	675/-

- The solar drying experiments were conducted on a regular basis from 8:00 a.m. to 4:00 p.m. for three consecutive days starting at 8:00 a.m. to 4:00 p.m., during March 2021 (Latitude 25.0108◦ N and Longitude 88.1411◦ E). During the experiment, the air temperature at the input and output of the solar collector and the drying chamber was measured using a k-type thermocouple. Based on the measured partial vapor pressure of water, web bulb temperature, and dry bulb temperature of air the various psychrometric properties such as relative humidity, specific humidity, and enthalpy were evaluated . Solar insolation on the surface of the collector was obtained by a pyranometer (SP-110 Pyranometer). An anemometer was used to monitor the flow rate of air at the solar collector inlet. All the thermo- couples and pyranometer were linked to a data logger to record the measured temperature and solar insolation data at regular time intervals. The obtained values were further used for energy and exergy analysis [10].

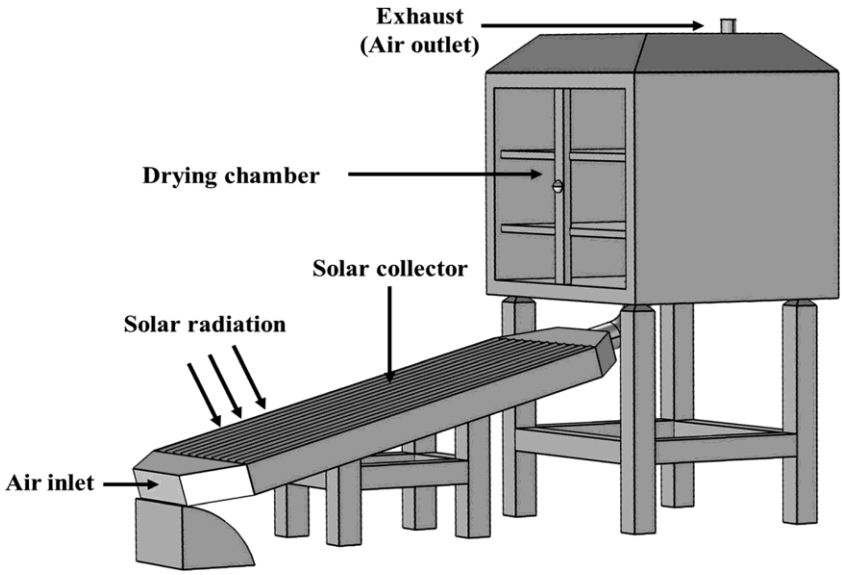


Figure 7: Experimental setup of flat plate collector solar dryer for drying of black cardamom

The black cardamom was dried in the flat plate collector solar dryer, and the energy and exergy studies of the drying process were conducted. The cardamom sample was sufficiently dried to obtain a final MC of approximately 0.09 kg water/kg dry matter at a mass flow rate of 0.018 kg/s. The energy consumption ratio is valuable for evaluating energy usage in the thin layer drying phase. As the energy consumption ratio (ECR) enhanced, the energy obtained from the solar collector was effectively used in the drying chamber. Exergy is a metric for energy efficiency, and it correctly represented the thermodynamic importance of solar drying. The higher exergy and lower thermal efficiency of the drying chamber demonstrated that a large amount of energy was wasted through the exhaust of the drying chamber. When exergy losses were lesser, the most effective use of exergy

was accomplished. This indirect type flat plate collector solar dryer can be used in agricultural and agro-industry settings for drying spices such as chilies, coriander, pepper, and turmeric, as well as a variety of other applications that require hot air for drying [4], [10].

- HR Capacity building at IHR: It was observed that these days the cultivators face lots of challenges in different stages of cultivation. All the challenges can be broadly divided in three categories, namely: i. challenges with plant are like diseases of virus and fungus. ii. issues related to market like price fluctuation and bargaining of middle man, and most importantly iii) lacking of trained human resources. The paper, in order to address the stated issues, has proposed a framework (Fig. 8) for the intervention of HR-CB by different government agencies [6], [19].

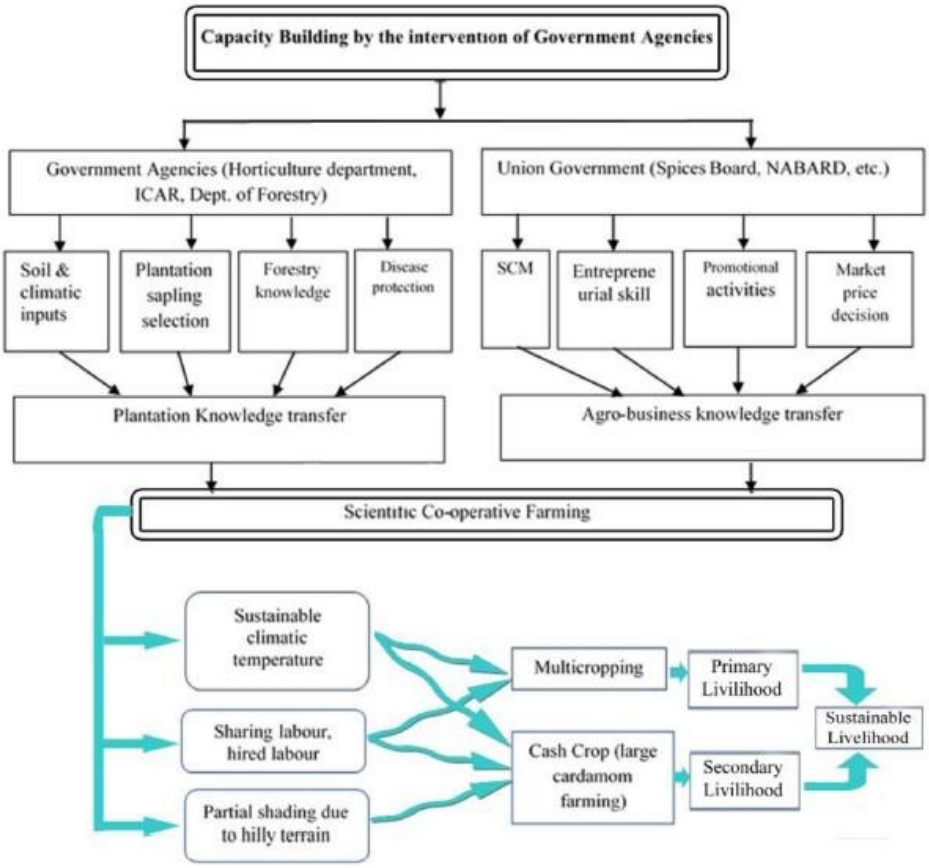


Figure 8: Model for HR Capacity building at IHR

Proposed model emphasized on the knowledge transfer for both plantation and agribusiness work. The plantation knowledge includes

i) soil, climatic condition, ii) selection of plantation sapling, iii) forestry knowledge, and iv) disease protection. This would build up confidence in portfolio management of plantation through site selection and cropping layout for appropriate farming. Similarly, the indigenous farmers lack the knowledge of agro-business knowledge, through HR-CB it can train farmers regarding i) supply

chain management, ii) entrepreneurial skill, iii) promotional activities, and iv) market pricing policy. The synergy of plantation knowledge, and agribusiness knowledge would augment the scientific co-operative farming. The favorable climatic, sharing and hiring of farmers would promote both Multicropping most for their self-consumption fulfilling their primary livelihood need, and the cash-crop like large cardamom would fulfil the clothing, shelter, education, medical and surplus saving aims towards secondary livelihood need. The proposed framework will augment the trained manpower through transfer knowledge on plantation and agro-business. It will help marginal farmers in scientific co-operative farming. Many educational institutes have initiated to streamline the linkage between various government agencies to for knowledge transfer in this locality [6], [19].

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets0

- Mass flow number of the solar collector as afunction of outlet temperature of the air

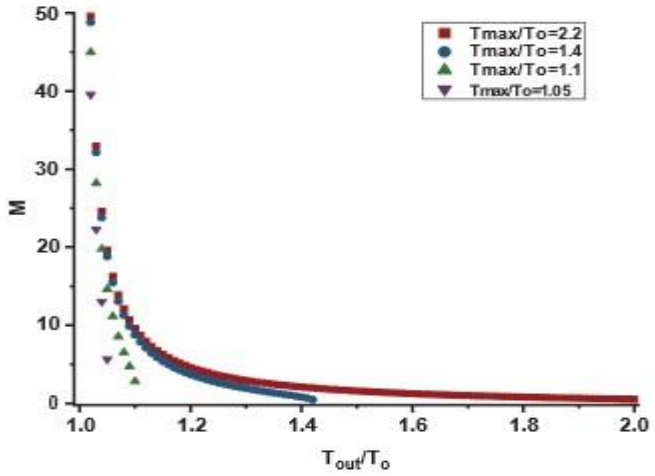


Figure 9: Mass flow number M of the solar collector as a function of outlet temperature of the air at various dimensionless maximum collector temperature

The results showed that an increase in the mass flow rate of air decreased the Ns value. The determination of the optimal area of the present solar collector was for minimum entropy generation, as this was the most appropriate formula for the present collector type. Depending on minimum entropy generation number Ns, the collection area for rectangular projection of solar collector was determined as 2.64 m^2. Fig.9 depicts the results of the mass flow number of the solar collector as a function of outlet temperature of the air, for different dimensionless maximum collector temperatures (θ_{max}) [4], [10].

- Variation of solar radiation and solar collector outlet temperature during drying

The experimental model described in the previous section of the solar dryer was tested with black cardamom during the present study. Experiments were carried out for 3 consecutive days, starting

at 8:00 a.m.to4:00p.m.,during March 2021. Fig.10 shows the plot of solar radiation measured, ambient air temperature recorded, and solar collector out let temperature versus drying time. Solar radiation values during the experiment ranged from 417.43 to 801.11W/m2 on the first day,393.97 to 812.61W/m2 on the second day, and 430.57 to 832.11 W/m2 on the third day. The ambient air temperature varied from 20.6 to 28.6^0 C, 21.6 to 29^0 C, and 22 to 29^0 C on the first, second, and third days, respectively. The break between the curves indicated the night duration. It was observed that the solar radiation increased in the first 4hr, reached a maximum value at 12:00–01:00 p.m., and then gradually decreased. The highest value of solar radiation recorded was 801.11, 812.6, and 832.1 W/m2 for the 3 consecutive days. Similar trends were observed with the ambient air temperature values. The maximum ambient air temperature values documented for 3 days were 28.6, 29.0, and 29.5^0 C, respectively. The highest values of the ambient air temperature were recorded at 01:00 p.m.

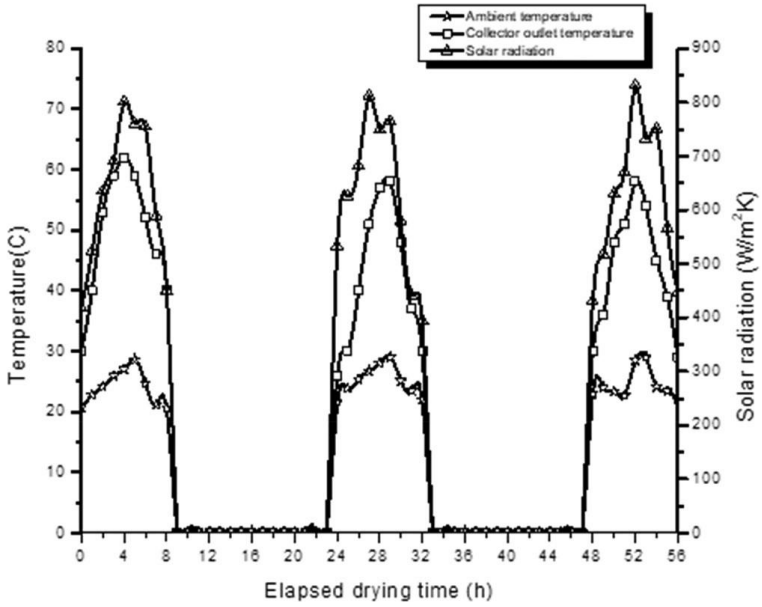


Figure 10: Solar radiation, ambient air temperature, and solar collector outlet air temperature versus elapsed drying time.

The outlet temperature increased linearly as the amount of solar energy increased during the day. At a solar irradiation level of 801.11W/m2, the maximum air temperature of the solar collector outlet was reported as 62^0 C for an input air temperature of 27^0 C. The maximum temperature gain in the collector during the peak afternoon period (1:00 p.m.) on all days was around 59^0 C (varying between 62 and 58^0 C). The outlet temperature of the solar collector during 3 days varied from 30–62^0 C, 26–58^0 C, and 29–58^0 C, respectively, at the mass flow rate of 0.018 kg/s [4], [10].

- Moisture content variation during solar drying of black cardamom

The decrease in moisture content (MC) (dry basis) of black cardamom as a function of drying time in a solar dryer is depicted in Figure 6. In this study, $t = 0$ in elapsed drying time axis corresponds to MC at 8:00 a.m. on the first day. The freshly harvested black cardamom was dried to 8.2% (wb) MC from an initial MC of 80.6% (wb) within 24 hr drying period. It was observed that the MC decreased with drying time at a constant airflow rate of 0.018 kg/s. The drop in MC was faster in the first 8 hr of drying than in the next 2 days. It was observed that when the ambi- ent air temperature increased, the relative humidity of the air declined to a minimum of 45% at 01:00 p.m. Hence, the faster drying rates were observed for increased ambient air temperature due to the corresponding increase in the solar insolation intensity. Figure 6 depicts the decrease in MC (dry basis) of black cardamom as a function of drying time in a solar dryer (6). T = 0 in the elapsed drying time axis corresponds to MC at 8:00 a.m. on the first day in this study. Within 24 hr, freshly harvested black cardamom was dried to 8.2% (wb) MC from an initial MC of 80.6% (wb). At a constant airflow rate of 0.018 kg/s, the MC decreased with drying time. The drop in MC was quicker in the first 8 hr of drying than in the next 2 days.

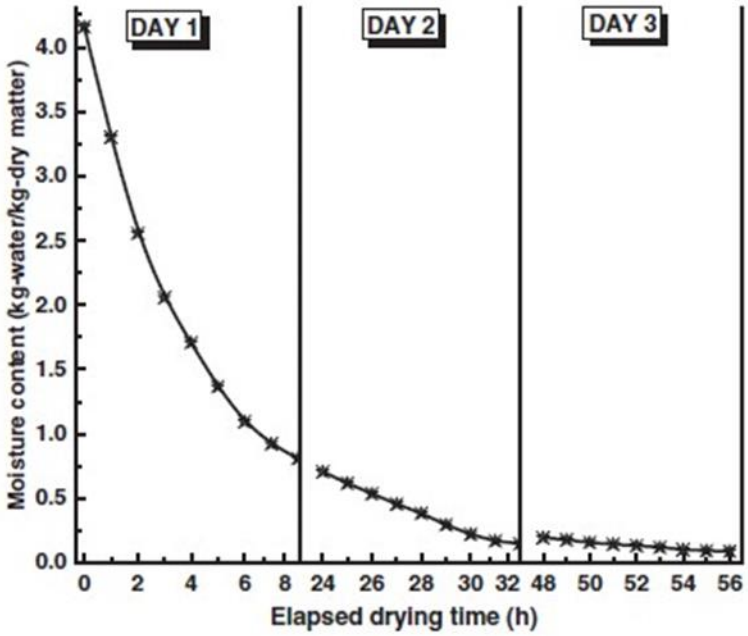


Figure 11: Moisture content versus elapsed drying time.

It was discovered that when the ambient air temperature increased, the relative humidity of the air declined to a minimum of 45% at 01:00 p.m. As the MC of the sample in the solar dryer declined, so did the moisture diffusion from the cardamom to the surroundings. Cardamom weight loss was initially faster due to unbound water on the outside surface but eventually slowed due to internal moisture migration from the interior layers to the surface. Solar drying of black cardamom drying followed a period of declining rates, that is, falling rate period. A study

on solar drying of Valeriana jatamansi using a forced convection solar dryer integrated with phase change material revealed that the drying rate was faster at the initial stage and then decreased significantly as drying time progressed (Bhardwaj, Chauhan, Kumar, Sethi, & Rana, 2017). This is consistent with the experimental data obtained during the solar drying of black cardamom [4], [10].

5.4 Technological Intervention

- The black cardamom was dried in the flat plate collector solar dryer, and the energy and exergy studies of the drying process were conducted. The cardamom sample was sufficiently dried to obtain a final MC of approximately 0.09 kg water/kg dry matter at a mass flow rate of 0.018 kg/s. The energy consumption ratio is valuable for evaluating energy usage in the thin layer drying phase. As the energy consumption ratio enhanced, the energy obtained from the solar collector was effectively used in the drying chamber. Exergy is a metric for energy efficiency, and it correctly represented the thermodynamic importance of solar drying. The higher exergy and lower thermal efficiency of the drying chamber demonstrated that a large amount of energy was wasted through the exhaust of the drying chamber. When exergy losses were lesser, the most effective use of exergy was accomplished. This indirect type flat plate collector solar dryer can be used in agricultural and agro-industry settings for drying spices such as chilies, coriander, pepper, and turmeric, as well as a variety of other applications that require hot air for drying [4], [10].
- The drying behaviour of larger cardamom was applied to nine different models in the literature to establish the drying kinetic model for the drying of large fresh cardamom. The two-term model delivered the best results among these models and showed good agreement with the experimental data obtained from the experiments, including the thin layer drying process. When the effects of drying air temperature on the constants and coefficients of the two-term model were examined, the R2, $\chi 2$ and RMSE values were found to be in the range of 0.9936-0.9970, 0.0002-0.020, and 0.0039-0.0188 respectively. Therefore, the two-term model adequately described the drying behaviour of large cardamom in the drying process within the temperature range of 50-80oC. The effective diffusivities increased with the drying temperature and varied from 1.949×10-10 to 3.898×10-10 m2/s. The temperature dependence of diffusivity follows the Arrhenius relationship, and the activation energy for the diffusion of moisture was found to be 32.55 kJ/mol [4], [10].
- As many actives, of machine nature, are currently being done manually. This leads to high cost, and time-consuming, resulting in low productivity, therefore, the project focused on achieving a cooperative sustainable farming system by replacing green energy sources with conventional ones. An electro-based FCS model was developed and proposed in the paper, the technical based FCS model, if implemented properly can result in various benefits such as providing a platform for communication with the outer world, a systematic and structured working pattern

where each one gets a clear idea about the work, increased production, economic development of farmers, market linkage, optimal utilization of land, organized source of employment, bulk surplus, being a cooperative, high valued machinery can be purchased, etc. the benefits are enormous. With this cooperative model, since people working jointly will bring the synergy and love of brotherhood can also be achieved. If implemented properly can also provide employment opportunities within the village as well [4], [10].

5.5 On field Demonstration and Value-addition of Products

On the field, the demonstration visit was joined by farmers, village representatives, and youths from the Mengio circle. The project implanting teams organized the field visit exposure program destination Sagalee village under the district Papumpare Arunachal Pradesh to integrated farms owned by Local progressive farmer Shri Techi Ramda.

The objectives of the visit:

- To visit Integrated farm to develop integrated farming techniques and practical experience with farming methods. And interaction with the owner to know the first-in-hand experience and their success story.
- To know how to implement the multiple crops concept to compensate for mere dependency on a single crop for livelihood.
- To grab and replicate the farm administration by owner the of Integrated farm Sagalee and take an overview of the complete process of farming activities for an overall sustainable agriculture model.
- To visit the modern large cardamom drying chamber processing unit owned by the progressive farmers from Sagalee village.
- Field Visit Observation Report : The field visits exposure program was conducted under the supervision of Project PI and other team members along with the farmers, village representatives, and youths from the Mengio circle to Sagalee village under the Papumpare District. The participants proceeded toward to Integrated farm and visited the farm and interacted with the farm owner and staff and had discussions with them related to the farming process and methods of the integrated farm which is a more profitable and sustainable way to increase the income. Also taken are accounts of an overview of tree planting, horticulture planting, animal husbandry activities, and integration of fishery along the large cardamom cultivation (multi crops farming). Besides the field visit observations, participants also visited the modern drying processor units installed by the progressive farmer without any help from government financial inclusion. They took the first-hand

experience with the dryer machine and acquainted with all the modern drying machines. Finally, had a discussion session with the progressive farmer, participants, and local village representatives.

5.6 Promoting Entrepreneurship in IHR

Considering the importance of entrepreneurship skills among the farmers a few steps were initiated under the project development objectives.

- To enhance the ability to participate directly with local, National, and international buyers, the ten selected members among the farmers were called and assisted them to participate in various SME development programs conducted under the different departments.
- Two-day seminar on 'Tribal empowerment through entrepreneurship of indigenous produced products' in collaboration with the GB Pant National Institute of Himalayan Environment & Sustainable Development and Assam-based Tezpur University,
- National SC/ ST Hub (NSSH) Conclave was held under the initiative of the MSME and the National Small Industries Corporation Limited (NSIC),
- Participated in National Buyers and Sellers meet organized by the APEDA, Arunachal Pradesh,
- Actively participated in World honeybee day Organised by the APAMB in collaboration with the APFPEDA.
- To easily access and integrate of local and national marketing information by local farmers one WhatsApp group was created, and all latest and large cardamom related relevant information is shared in the group.
- To increase the financial capacity of local farmers, while prioritising the pooling of funds, and accessing group guarantees for availing bank loans, a FCS was formed under the Name of PMCSL.

5.7 Developing Green Skills in IHR

- In its bid to spread awareness and develop green skills among the farmers and communities, the project team initiated awareness programs in response to unchecked forest clearance for large cardamom cultivation and to preserve the wild honeybee as great pollinators of nature. The objectives of these programs are, to sensitize the local farmers and communities to preserve the forest and exploit its blessing in sustainable ways. Appreciating the importance of preserving or restoring an environmentally sustainable future the first initial stage was, to organize a tree planting event and a short session interaction program also conducted with participants from the farmers' communities, village representatives, and students.

- Tree planting program was organized and planted 150 plants with the Government secondary school Sakiang Mengio and nearby government offices. A large number of students and villagers took part in the program.

- In the second stage, an awareness program cum visual presentation session was conducted under the supervision of the project team. The theme of the event was “Save bumble bees as your pollinators”. A session was attended by village farmers, village representatives, and student communities in large numbers. A complete visual presentation was demonstrated with help of pictures and small videos to make us understand and appreciate the role of pollinators like bumblebees and other flies.

- Contemporary sustainable farming balances higher productivity with a focus on green technological intervention. Green interventions such as renewable energy has been widely accepted by other sectors, farming community has yet to yield the dividend from the tool. In this project, a modified technology acceptance model has been presented with a focus towards the adaptability of actually sustainable farming.

5.8 Addressing Cross-cutting Issues

- There is a significant positive relationship observed between the variables implementing green energy and Information Communication and Technology (ICT), perceived utility, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation, according to the findings obtained. Farmers with minimal access to resources, energy, and technology can access information. The analysis offers valuable perspectives for farmers and decision-makers of implementing ICT and renewable energy for sustainable agriculture [37].

- The proposed knowledge transformation would augment the SL. The intervention of HR-CB through the support of government in the said areas can ensure SL through large cardamom cultivation along with multi-cropping practices by the marginal farmers. On successful implementation of the proposed framework in the said region, it can act as role model for similar climatic and terrain condition [6], [19].

- The indigenous system are interdependent on three components: social security, conservation of environment, and self- consumption based farming. These three components can be further sharpened through the inclusion of components of FPC like organic certification, financial aid for farm inputs, warehousing, logistic, marketing, and commercialization of surplus production for livelihood [1].

6 PROJECT'S IMPACTS IN IHR

6.1 Socio-Economic Development

- Creating a path for the augmentation of physical capital by creating awareness about new agricultural practices like multi-layer farming, financial capital by the formation of FCS, human capital through the training related to all aspects of large cardamom farming and marketing, and natural resources management.

- Building core competencies in the entrepreneurial skill sets like product management, packaging and branding amongst the local inhabitants.

- Development of technological capabilities by the knowledge enrichment in terms of green technology like solar PV based electrification.

- The project can be a role model for other collaborative farming by the flows of knowledge and technology among other cooperatives will enhance the production linkages.

- Similarly the project will foster collaborative farming by the business linkages both forward in terms of marketing of the products, and backward integration for the input related to the farming, and allied technological activities.

6.2 Scientific Management of Natural Resources In IHR

- In many different parts of the world, electricity is being used in the agriculture sector and is getting maximum benefit too. But it is found that modern technology-based agro farming is depending upon energy supply obtained from fossil fuels or we can say the conventional source of electricity. Fossil hydrocarbon is a limited source to rely on completely and also its harmful effect on the environment creates need for reducing their use. By this agriculture, which meant to be the highest livelihood provider, ultimately resulting in one of the major emitters of greenhouse gas. This question is about the sustainability of the environment. The continued use of fossil fuel may lead to a slowdown of production in near future causing serious issues to the agricultural sector. Many researchers on their different studies have proved that a renewable source of energy is the best to rely on to avoid a negative impact on the environment created by the conventional source of energy supply. Collation of available scientific information and data on climate change pertaining to the said region by the HOMOR software [16].

- The fresh black cardamom (A. subulatum) samples were obtained from a local farm located in Itanagar, Arunachal Pradesh, India. Grading of cardamom was done on the basis of their size and color. Dark colored (brownish-red color) capsules were chosen for the drying experiment. The experimental setup consisted of four main elements, which included (i)

solar collector, (ii) drying chamber, (iii) exhaust, and (iv) data logger. During the solar drying process, the ambient air was heated up to a certain temperature through the solar air collector, and afterward, it was passed to the drying chamber. The drying chamber was made of galvanized iron material. The drying chamber had insulated layers of polyurethane also. The drying cabinet had two aluminum trays in between the top and bottom sur- face of the drying chamber, and the vertical spacing between two consecutive trays was 20 cm. The hot, humid air released after drying was passed to the exterior through the chimney provided on top of the drying chamber. The various components of the solar dryer were connected through foam-insulated PVC pipe. The entire system was completely instrumented, and a special allowance was included in calculating the properties of solar radiation and environmental parameters. The drying experiments were performed in the designed solar dryer to determine the output parameters at various air mass flow rates [4], [10].

- Farming system approach for synergizing conservation and development by creating awareness about the jhum cultivation. People's perceptions on climate change and its impacts and, where appropriate, establishing if these have scientific bases and validity.

- Information collected related to customs and traditional knowledge in respect to natural resources management and utilization.

6.3 Conservation of Biodiversity in IHR

- Training and awareness programs have educated the local inhabitant at the project site, which changed inclinations for biodiversity protection and have worked on the execution of biodiversity reactions.

- On account of biodiversity preservation, the test is in arranging these compromises, deciding degrees of acceptable biodiversity misfortune, and encourage support.

- Agribusiness of large cardamom may prompt loss of biodiversity yet can in any case add to local biodiversity in the event that it contributes specific complementary components of biodiversity to generally territorial biodiversity preservation.

- Costs and benefits of the conservation strategies and their commitment to human development are being perceived.

6.4 Protection of Environment

- Environmental protection is a social and political undertaking with its own goals. So the advantage of potential collaborations between ecological arrangement and employment is

accordingly valuable. The current project has created the scope of employability with the help of environment protection.

- The sustainable source of energy and unrefined substance effectiveness is assuming an undeniably significant part in numerous ventures. In the radiance of this improvement, organizations have a significant motivating force to situate themselves well in "green future business sectors" like large cardamom drying with the help of an electrified dryer.

- Ecological security such as waste management like the produced large cardamom were wasted earlier due to direct heating method, soil erosion control by multi layer farming, air quality control due to smoke less drying, and sustainable power sources that positions are being made.

6.5 Developing Mountain Infrastructures

- Sustainability aspects of mountain development including effect of environmental change, environment policies, anticipating calamity planning has been carried out by creating awareness regarding control of deforestation.

- The development of the mountainous areas by improving access to sightseeing spots such as large cardamom farming sites and other multilayer farming along the line. Thus it will create scope for eco-tourism, and destination branding due to large cardamom farming and its marketing.

- Inconvenient transport areas of mountains have big handicaps in all areas of life, such as employment, education, culture, medical care, welfare, and consumption. They face serious regional problems like declining livelihood in the local populations. The scope for the livelihood through the intervention of this project will definitely boost the mountain infrastructure in terms of human infrastructure of the said region.

6.6 Strengthening Networking in IHR

- Entrepreneurship through the FCS initiatives would increase the visibility of the indigenous people in the other parts of the IHR, establishing both forward and backward networking.

- It will facilitate business exchange platforms, fairs, business associations, business portals, and clubs.

- The business ecosystem would engage the other community in local entrepreneurship networks.

7 EXIT STRATEGY AND SUSTAINABILITY

7.1 How effectively the project findings could be utilized for the sustainable development of IHR

The increasing population creates challenges for each individual on the planet, who needs resources to survive, and thus the stress on the earth to supply these will likewise develop. Although a bigger population by and large means more mouths care for, there is not an even utilization all through the world. One of the greatest marks of impracticality is in the misdistribution of riches. Over one-third of the world actually lives in neediness with restricted admittance to energy, water, and food. Population growth is a lot higher in the underdeveloped and developing world, while resource utilization and pollution are higher in the developed region. The focal point of sustainability is on humankind (the social angle of the sustainability triangle) for all intents and purposes on nature (the ecosystem), and to decrease this imbalance and give a fundamental way of life conditions for the world's occupants is vital to the manageability challenge [41]. By and large, they depend on ideas of humankind innately making progress toward endurance.

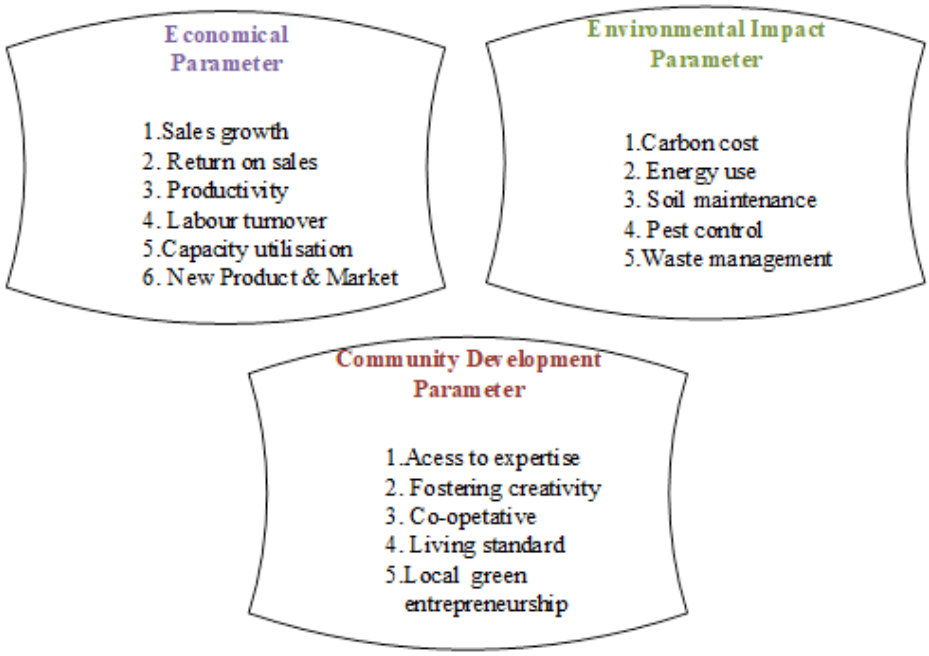


Figure 12: Sustainable development of IHR

The following are three perspectives of sustainability covered in this project:

- Environmental impact doesn’t see the human race as a separate entity from the planet and but as part of it. Their inspirations for safeguarding the planet are that nature and mankind have innate worth and hence ought to be safeguarded. The current project deals with carbon costs by reducing deforestation as well as air pollution due to burning of the wood logs. Similarly, renewable sources of energy use like solar PV, and soil maintenance

by avoiding artificial chemical pest control and proper waste management have been addressed appropriately to deliver the desired output for the environmental aspects.

- The economical parameters comprehend the proportions of unreasonableness emerging from a consumer-led culture as limited resources as an income, yet has confidence that market forces and a “business as usual” move toward will bring about a characteristic emergency revolution happening, the framework will get itself straightened out through innovative advances. The economic parameter like sales growth, return on sales, productivity, labor turnover, capacity utilization, and new product and market with the help of the large cardamom and other multilayer farming will definitely increase the scope of the local inhabitant to achieve the economic aspects of the sustainability.
- Community development has been the intersection of varied characteristics like access to expertise in agricultural practices, fostering creativity, and formation of FCS for the mutual benefits of the farming community. The project also offers local green entrepreneurship to the local marginal farmers.

7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR

The studied area of the project resembles with the other IHR in the socio-cultural, economical, and ecological factors. The increasing population creates challenges for resources to survive, and thus the stress on to supply these. Although a bigger population there is not an even utilization all through the world. One of the greatest marks of impracticality is in the misdistribution of resources. The majority of the IHR inhabitants suffer a deficiency of energy, water, and food. The focal point of sustainability is on humankind (the social angle of the sustainability triangle) for all intents and purposes on nature (the ecosystem), and to decrease this imbalance and give a fundamental way of life conditions for the IHR’s occupants is vital to the manageability challenge. By and large, they depend on ideas of humankind innately making progress toward endurance. The following are three perspectives of sustainability that can be covered in the other states of the IHR:

- Environmental impact has the inspirations for safeguarding the IHR are that nature and mankind have innate worth and hence ought to be safeguarded. The current project deals with carbon costs by reducing deforestation as well as air pollution due to burning of the wood logs. Similarly, renewable sources of energy use like solar PV, and soil maintenance by avoiding artificial chemical pest control and proper waste management have been addressed appropriately to deliver the desired output for the environmental aspects. These are generic issues that can be adopted by all the other IHR states as all of these falls under the biodiversity region. Hence the environmental impact has to be addressed in the same manner by adopting a green source of technological intervention like a green source of energy, avoidance of chemical pest control, and appropriate waste management.

- The economical parameters parameter like sales growth on a continual basis, return on sales in an increasing trend, the productivity of all the resources including the raw materials and marketing expenses, labor turnover, capacity utilization, and new product for each niche market with the help of the large cardamom or any other niche product with other multilayer farming will definitely increase the scope of the local inhabitant to achieve the economic aspects of the sustainability.
- Community development has been the intersection of varied characteristics like access to expertise in agricultural practices, fostering creativity, and formation of FCS for the mutual benefits of the farming community. The project also offers local green entrepreneurship to the local marginal farmers.

The project strategy can constitute 1) Pre-Project evaluation strategy: An evaluation group may be constituted consists of faculty experts from the institute, experts from different concerned departments (State and Central Governments) and local inhabitants through seminars to suggest regarding risk evaluation of the project. 2) Post-Project evaluation strategy: Post-project evaluation may be carried out ascertaining that the project resources are used effectively to bring the project in on time, within budget, and with satisfactory technical performance. The evaluation strategy may include: (1) the performance standards derived from the project objectives, goals, and strategies; (2) the performance measurement techniques; (3) a comparison of planned and actual performance; and (4) the corrective action required to get the project back on track.

7.3 Identify other important areas not covered under this study needs further attention

In IHR, the drones will play the role of an autonomous bird to drop the first aid, and medical necessities urgently needed. In rescue and search operations, drones will help the rescue and search team locate the victim providing them a bird’s eye view as the IHR have many inhabited areas where people have no access to roads generally covered with thick flora and diverse fauna. These avenues will surely throttle Study area to attain the so-adjudged developed stage. In the agriculture system of IHR, ICT and renewable are used in weather forecasting, taking expert opinion, and farming techniques by illustrative video. Renewable energy was implemented for generating and storage of electricity which further can be implemented for electricity-based water pumps and storage of farm output. The IHR farmers are lesser interested in the implementation of ICT in agriculture due to their low level of education, and the higher initial cost of investment for implementing the technology. The IHR farmers often risk introducing the technique because they are not sure about the yield. ICT is mainly dependent on electricity. Privatized mega-power plants can't afford less efficient rural electrification, so green energy can help marginal farmers make it sustainable through partnership at the village level [37].

HR- CB for the indigenous farming community in the IHR for the proposed knowledge transformation would augment SL. The intervention of HR- CB in the IHR through the support of the

sponsored project in the said areas can ensure SL through sustainable cultivation along with multi-cropping practices by marginal farmers. On successful implementation of the proposed framework in the said region, it can act as a role model for similar climatic and terrain conditions [19].

7.4 Major recommendations for sustaining the outcome of the projects in future

This project will provide supplementary livelihood options for the remote rural inhabitants in this region. It will also help in enhancing the CB of the rural IHR by providing sustainable infrastructure development and will enhance the energy security. It will be helpful for sustainable development of the rural people staying in the IHR by adding value to the livelihood of the cardamom growers. It can be sustained in future by

- Empowering women farmers with better methods and marketing scope that would improvise sustainability, hence they should be allowed facilitate to acquire such skills after a certain time span.
- The scientific way of cardamom farming would reduce the burden of carbon cost, hence it has to be more popularized by the awareness program in time intervals.
- Besides, the proposed scheme is “by the people, for the people”, and the success of the FCS will generate employment for the villager. Hence the helps, advisory from time to time may also to be extended to this project.

8 REFERENCES/BIBLIOGRAPHY

[1] Biman, P., Parida, A., Choudhury, S., & Chatterjee, S. (2019, December). Augmenting Farmer Producer Company through Aligning Indigenous Community Based Beliefs and Practices: Learnings from Abotani Community of Eastern Himalayan Region. In Proceedings of the 2nd International Conference on Information Systems &Management Science (ISMS).http://dx.doi.org/10.2139/ssrn.3511431

[2] Deng, Z., Li, M., Xing, T., Zhang, J., Wang, Y., & Zhang, Y. (2021). A literature research on the drying quality of agricultural products with using solar drying technologies. *Solar Energy*, *229*, 69-83, https://doi.org/10.1016/j.solener.2021.07.041.

[3] Lata, K., Mande, S., & Kishore, V. (2000). Studies on quality improvement of large-cardamom using an advanced gasifier based dryer. New Delhi: Tata Energy Research Institute.

[4] Dash, S., Dash, K. K., & Choudhury, S. (2021). Evaluation of energy efficiency and moisture diffusivity for convective drying of large cardamom. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012016). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012016

[5] Udomkun, P., Romuli, S., Schock, S., Mahayothee, B., Sartas, M., Wossen, T., ... & Müller, J. (2020). Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach. *Journal of Environmental management*, *268*, 110730, https://doi.org/10.1016/j.jenvman.2020.110730

[6] Hatiboruah, J., Pant, R. M., & Choudhury, S. (2021). Reinforcing Livelihood by Interdependency of HR Capacity-ICT: Relevance to Multi-cropping practice system in Indian Eastern Himalaya. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012014). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012014

[7] Singh, R. K., Singh, A., Ksherchokpa, L., Rallen, O., Taniang, B., Lego, Y. J., ... & Mauerhofer, V. (2021). Grassroots approaches for sustaining biocultural diversity and livelihood Security: insights from Indian eastern Himalaya. *Environmental Management*, *68*(1), 17-37, https://doi.org/10.1007/s00267-021-01462-1.

[8] Singh, R. K., Zander, K. K., Kumar, S., Singh, A., Sheoran, P., Kumar, A., ... & Garnett, S. T. (2017). Perceptions of climate variability and livelihood adaptations relating to gender and wealth among the Adi community of the Eastern Indian Himalayas. *Applied Geography*, *86*, 41-52, http://dx.doi.org/10.1016/j.apgeog.2017.06.018.

[9] Priyadarshini, P., & Abhilash, P. C. (2019). Promoting tribal communities and indigenous knowledge as potential solutions for the sustainable development of India. Environmental Development, 32, 100459. https://doi.org/10.1016/j.envdev.2019.100459

[10] Dash, S., Choudhury, S., & Dash, K. K. (2022). Energy and exergy analyses of solar drying of black cardamom (Amomum subulatom Roxburgh) using indirect type flat plate collector solar dryer. *Journalof Food Process Engineering*, *45*(4), e14001. http://dx.doi.org/10.1111/jfpe.14001

[11] Tahiru, A., Sackey, B., Owusu, G., & Bawakyillenuo, S. (2019). Building the adaptive capacity for livelihood improvements of Sahel Savannah farmers through NGO-led adaptation interventions. *Climate Risk Management*, *26*, 100197, https://doi.org/10.1016/j.crm.2019.100197.

[12] Vladimir Milovanovic, Lubos Smukta, (2018) Cooperative rice farming within rural Bangladesh, Journal of Cooperative Organization and Management, vol. 6, pp. 11-19. https://doi.org/10.1016/j.jcom.2018.03.002

[13] Singh, R. K., Singh, A., Garnett, S. T., Zander, K. K., & Tsering, D. (2015). Paisang (Quercus griffithii): a keystone tree species in sustainable agroecosystem management and livelihoods in Arunachal Pradesh, India. *Environmental management*, *55*(1), 187-204, https://doi.org/10.1007/s00267-014-0383-y.

[14] Singh, R. K., Bhardwaj, R., Sureja, A. K., Kumar, A., Singh, A., Hazarika, B. N., ... & Rallen, O. (2022). Livelihood resilience in the face of multiple stressors: biocultural resource-based adaptive strategies among the vulnerable communities. *Sustainability Science*, *17*(1), 275-293, https://doi.org/10.1007/s11625-021-01057-z.

[15] Wacker G John, (1998) A definition of theory: research guidelines for different theory-building research methods in operations management, Journal of Operations Management, vol. 16, pp. 361-385.

[16] Athira, R., Parida, A., & Choudhury, S. (2021). Significance of Renewable Energy for Empowering Cooperative-Farming Sector in Majuli Island of India. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012021). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012021
[17] Touil, S., Richa, A., Fizir, M., & Bingwa, B. (2021). Shading effect of photovoltaic panels on horticulture crops production: a mini review. *Reviews in Environmental Science and Bio/Technology*, *20*(2), 281-296, doi:10.1007/s11157-021-09572-2.
[18] Choi, C. S., Cagle, A. E., Macknick, J., Bloom, D. E., Caplan, J. S., & Ravi, S. (2020). Effects of revegetation on soil physical and chemical properties in solar photovoltaic infrastructure. *Frontiers in Environmental Science*, 140, https://doi.org/10.3389/fenvs.2020.00140
[19] Hati Boruah, J., Mohan Pant, R., & Choudhury, S. (2020). Sustainable livelihood by HR capacity building in multi-cropping practices of Indian Eastern Himalayan region: A case study. *Journalof Statistics and Management Systems*, *23*(2), 277-284. http://dx.doi.org/10.1080/09720510.2020.1724626
[20] Gautam, N., Bhattarai, R. R., Khanal, B. K. S., & Oli, P. (2016). Technology, chemistry and bioactive properties of large cardamom (Amomum sub- ulatum Roxb.): An overview. International Journal of Applied Sciences and Biotechnology, 4(2), 139–149.
[21] Seveda, M., & Jhajharia, D. (2012). Design and performance evaluation of solar dryer for drying of large cardamom (Amomum subulatum). Journal of Renewable and Sustainable Energy, 4(6), 063129.
[22] Sultana, M., Ahmed, J. U., & Shiratake, Y. (2020). Sustainable conditions of agriculture cooperative with a case study of dairy cooperative of Sirajgonj District in Bangladesh. *Journal of Co-operative Organization and Management*, *8*(1), 100105, https://doi.org/10.1016/j.jcom.2019.100105.
[23] Huang, Z,.-h., et al., (2015) Situational features and governance structure of farmer cooperatives in China: Does initial situation matter?", The Social Science Journal, vol. 53, pp. 100-110. http://dx.doi.org/10.1016/j.soscij.2015.09.003
[24] Gupta, S. R., Dagar, J. C., & Teketay, D. (2020). Agroforestry for rehabilitation of degraded landscapes: achieving livelihood and environmental security. *Agroforestry for Degraded Landscapes*, 23-68, https://doi.org/10.1007/978-981-15-4136-0_2.
[25] Singh, S. (2020). Bridging the gap between biophysical and social vulnerability in rural India: a community livelihood vulnerability approach. *Area Development and Policy*, *5*(4), 390-411, https://doi.org/10.1080/23792949.2020.1734473.
[26] Siraw, Z., Bewket, W., & Adnew Degefu, M. (2020). Assessment of livelihood benefits of community-based watershed development in northwestern highlands of Ethiopia. *International Journal of River Basin Management*, *18*(4), 395-405, https://doi.org/10.1080/15715124.2018.1505733.
[27] Bardi Ugo, Asmar El Toufic, Lavacchi Alessandro, "Turning electricity into food: the role of renewable energy in the future of agriculture", Journal of Cleaner Production, vol. 53, pp. 224-231, 2013. https://doi.org/10.1016/j.jclepro.2013.04.014
[28] Fang Xingming, et al., "Gap between words and actions: Empirical study on consistency of residents supporting renewable energy development in China", Energy Policy, vol. 148, pp. 111945, 2021. https://doi.org/10.1016/j.enpol.2020.111945
[29] Apostolopoulos Nikolaos, et al., "The role of the expert knowledge broker in rural development: Renewable energy funding decisions in Greece", Journal of Rural Studies, vol. 78, pp. 96–106, 2020. https://doi.org/10.1016/j.jrurstud.2020.06.015
[30] Gorjian, S., Singh, R., Shukla, A., & Mazhar, A. R. (2020). On-farm applications of solar PV systems. In *Photovoltaic solar energy conversion* (pp. 147-190). Academic Press, https://doi.org/10.1016/B978-0-12-819610-6.00006-5.
[31] Gorjian, S., Ebadi, H., Trommsdorff, M., Sharon, H., Demant, M., & Schindele, S. (2021). The advent of modern solar-powered electric agricultural machinery: A solution for sustainable farm operations. *Journal of Cleaner Production*, *292*, 126030, , https://doi.org/10.1016/j.jclepro.2021.126030.
[32] Lalrochunga, D., Parida, A., & Choudhury, S. (2020). Sustainability of UAVs in developing countries: Prospects and challenges. Journal of Discrete Mathematical Sciences and

Cryptography, 23(1), 237- 248. https://doi.org/10.1080/09720529.2020.1721887
[33] Aroonsrimorakot, S., Laiphrakpam, M., & Paisantanakij, W. (2020). Solar panel energy technology for sustainable agriculture farming: A review. *International Journal of Agricultural Technology*, *16*(3), 553-562.
[34] Gudo, A. J. A., Belete, M., Abubakar, G. A., & Deng, J. (2020). Spatio-Temporal Analysis of Solar Energy Potential for Domestic and Agricultural Utilization to Diminish Poverty in Jubek State, South Sudan, Africa. *Energies*, *13*(6), 1399, https://doi.org/10.3390/en13061399.
[35] R, Athira and Parida, Adikanda and Choudhury, Shibabrata, ProposedCooperative Farming as a Catalyst to Livelihood Augmentation for the Marginal Farmers in Majuli Island (January 1, 2020). Proceedings of the 2nd International Conference on Information Systems & Management Science (ISMS) 2019 | Tripura University, Agartala, Tripura, India, Available at SSRN: https://ssrn.com/abstract=3512400 or http://dx.doi.org/10.2139/ssrn.3512400
[36] Tran, Q. B., Nguyen, T. P. T., Le, T. N., Schnitzer, H., Braunegg, G., Le, S., ... & Van Le, Q. (2020). Integrated farming system producing zero emissions and sustainable livelihood for small-scale cattle farms: Case study in the Mekong Delta, Vietnam. *Environmental Pollution*, *265*, 114853, https://doi.org/10.1016/j.envpol.2020.114853.
[37] Dash, S., & Choudhury, S. (2021). Adopting Sustainable Farming: Implications of Renewable Energy and ICT. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p.012018). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012018
[38] Fathoni S Hilman, et al., “Is community renewable energy always just? Examining energy injustices and inequalities in rural Indonesia”, Energy Research & Social Science, vol. 71, pp. 101825, 2021. https://doi.org/10.1016/j.erss.2020.101825
[39] Clausen Tolnov Laura, et al., “Renewable energy for sustainable rural development: Synergies and mismatches”, Energy Policy, vol. 138, pp. 111289, 2020. https://doi.org/10.1016/j.enpol.2020.111289
[40] Gargallo P, et al., “Perceptions of local population on the impacts of substitution of fossil energies by renewables: A case study applied to a Spanish rural area”, Energy Reports, Vol. 6, pp. 436-441, 2020. https://doi.org/10.1016/j.egyr.2019.08.085
[41] https://www.futurelearn.com/info/courses/sustainability-society-and-you/0/steps/4618#:~:text=Sustainability%20is%20often%20represented%20diagrammatically,environmental%20protection%20and%20social%20equity.

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(Shibabrata Choudhury)

Annexure-I

Consolidated and Audited
Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: 2018-2021

1.	Title of the project/Scheme/Programme:	Large Cardamom and Other Multilayer Innovative Farming in Mengio Circle of Arunachal Pradesh and Its Impact on Sustainable Rural Livelihood
2.	Name of the Principle Investigator & Organization:	Dr. Shibabrata Choudhury Centre for Management Studies North Eastern Regional Institute of Science and Technology (NERIST) Nirjuli, Arunachal Pradesh-791109
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	Ref. No.: GBPNI/NMHS-2017-18/SG15 Date: 28-03-2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	₹19,46,000.00 received on 4th September, 2018.
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	₹19,46,000.00

6.	Actual expenditure (excluding commitments) incurred during the project period:	₹15,08,400.00
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	₹5,17,264.00 amount returned vide cheque number 047140 of SBI, dated 17-06-2022.
8.	Balance amount available at the end of the project:	₹5,17,264.00
9.	Balance Amount:	₹4,37,600.00
10.	Accrued bank Interest:	₹79,664.00

Certified that the expenditure of **₹15,08,400.00 (Rupees Fifteen Lakhs Eight Thousand and Four Hundred only)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[North Eastern Regional Institute of Science and Technology, Arunachal Pradesh]

Statement showing the expenditure of the period from

Sanction No. and Date :Ref. No.: GBPNI/NMHS-2017-18/SG15 Date: 28-03-2018

1. Total outlay of the project : ₹15,08,400.00

2. Date of Start of the Project : 28-03-2018

3. Duration : 3 years

4. Date of Completion : 28-03-2021

a) Amount received during the project period : ₹19,46,000.00

b) Total amount available for Expenditure : **₹19,46,000.00**

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1	Salaries	396000	490426	-94426
2	Travel (Domestic)	200000	146243	53757
3	Consumable			.00
4	Contingency	50000	45000	5000
5	Activities & Other Project cost	500000	148400	351600
6	Institutional charges/Overhead			.00
7	Accrued bank Interest			79664
8	Equipment	800000	678331	121669
	Solar Grid-tied PCW inverter 10kW (Delta)		222000	
	Polycrystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW including installation and commissioning		200000	

	Solar PV supported electric dryer		256331	
	GRAND TOTAL	1946000	1508400	517264

Certified that the expenditure of **₹15,08,400.00 (Rupees Fifteen Lakhs Eight Thousand and Four Hundred only)** mentioned against Sr. No.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY

NATIONAL MISSION ON HIMALYAN STUDIES (GBP NIHE)

Annexure-II

Consolidated Interest Earned Certificate

A consolidated interest amount of ₹ 79,664 (Rupees Seventy Nine Thousand Six Hundred Sixty Six only)has been earned in FY 2018-19, 2019-20, 2020-21.

(Signature of Principal Investigator)	(Signature of Registrar/ Finance Officer)	(Signature of Head of the Institution)

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: National Mission on Himalayan Studies (NMHS), Almora, Uttarakhand.

1. Sl. No. 1 & 2
2. Name of Grantee Institution: North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh
3. No. & Date of sanction order: PUR/167/NMHS/SC/CMS/2018-19 DATED 19-02-2019 (Project registrar page no- 06, 08, 10, 12, 14, 16, 18, and 20)
4. Amount of the Sanctioned Grant: ₹8,00000/- (combined value for Sl.no 1, 2, & 3)
5. Brief Purpose of the Grant: Regarding Grid connected distributed renewable electrification
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: transferred to NERIST
7. Particulars of assets actually credited or acquired: acquired
8. Value of the assets as on : ₹ 4,22,000/- (Booked value without depreciation)
9. Purpose for which utilised at present : both academic demonstration & electrification to NERIST
10. Encumbered or not : Not encumbered
11. Reasons, if encumbered : Not applicable
12. Disposed of or not : Not
13. Reasons and authority, if any, for disposal: Not applicable
14. Amount realised on disposal: Not applicable
15. Any Other
16. Remarks:

Name of the Sanctioning Authority: National Mission on Himalayan Studies (NMHS), Almora, Uttarakhand.

1. Sl. No. 3
2. Name of Grantee Institution: North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh
3. No. & Date of sanction order: multiple dates

4. Amount of the Sanctioned Grant: ₹8,00000/- (combined value for Sl.no 1, 2, & 3)
5. Brief Purpose of the Grant: Regarding Grid connected distributed renewable based large cardamom dryer
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: transferred to NERIST
7. Particulars of assets actually credited or acquired: acquired
8. Value of the assets as on : ₹ 2,56,331/- (Booked value without depreciation)
9. Purpose for which utilised at present : both academic demonstration & practical usage at NERIST
10. Encumbered or not : Not encumbered
11. Reasons, if encumbered : Not applicable
12. Disposed of or not : Not
13. Reasons and authority, if any, for disposal: Not applicable
14. Amount realised on disposal: Not applicable
15. Any Other
16. Remarks:

(PROJECT INVESTIGATOR) **(FINANCE OFFICER)**

(Signed and Stamped) **(Signed and Stamped)**

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details
1	Solar Grid-tied PCW inverter 10kW (Delta)	1set		₹2,22,009.4	
	a) Ms ground mounting structure for 5 kW				
	b) AJ Box				
	c)16 mm wire				
	d) 4 mm wire				
	e) 20 mm wire				
	f) LA, GI Pipe, GI Strip, for earthing.				
	g)MCB with fitting				
	h) SPT single				
	i)25 mm PVC pipe				
	j) MC4 connector				
	k) DC Solar wire				
2	Poly crystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW including installation and commissioning	1set		₹2,00,000.25	
3	Electric Dryer	1 no		₹2,56,331.00	

(PROJECT INVESTIGATOR) **(FINANCE OFFICER)**

(Signed and Stamped) **(Signed and Stamped)**

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-V

Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department

To,

The Convener, Mountain Division
Ministry of Environment, Forest & Climate Change (MoEF&CC)
Indira Paryavaran Bhawan
Jor Bagh, New Delhi-110003

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "LARGE CARDAMOM AND OTHER MULTILAYER INNOVATIVE FARMING IN MENGIO CIRCLE OF ARUNACHAL PRADESH AND ITS IMPACT ON SUSTAINABLE RURAL LIVELIHOOD" funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

This is hereby certified that the following permanent equipment purchased under the aforesaid project have been transferred to the Implementing Organization/ Nodal Institute after completion of the project:

1. Solar Grid-tied PCW inverter 10kW (Delta)
2. Ms ground mounting structure for 5 kW
3. Polycrystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW
4. Electric Dryer

Head of Implementing Organization:
Name of the Implementing Organization:
Stamp/ Seal:
Date:

Copy to:

1. The Nodal Officer, NMHS-PMU, National Mission on Himalayan Studies (NMHS), G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand-263643

Annexure-VI

Details, Declaration and Refund of Any Unspent Balance

Refund of unspent balance of amount ₹5,17,264 (Rupees Five Lakhs and Seventeen Thousand and Sixty Four only) has been transferred through RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Bank A/c Details as follows:

Name of NMHS A/c	**:** NMHS GIA General
Bank Name & Branch	**:**Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code	**:** CBIN0281528
Account No.	**:** 3530505520 (Saving A/c)

(PROJECT INVESTIGATOR)
(Signed and Stamped)

(FINANCE OFFICER)
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Appendix 1 Details of Technical Activities

Pic 20: Solar energy park at NERIST.

Appendix 2 **Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS**

APPENDIX-II: Publication Details

S. No	Particular of publication	Name of publisher	Impact factor	Indexed in	Journal/conference proceeding
1	Dash, S., Choudhury, S., & Dash, K. K. (2022). Energy and exergy analyses of solar drying of black cardamom (Amomum subulatom Roxburgh) using indirect type flat plate collector solar dryer. *Journal of Food Process Engineering*, *45*(4), e14001. http://dx.doi.org/10.1111/jfpe.14001	Willey	2.9	SCI Web of Science	Journal
2	Hati Boruah, J., Mohan Pant, R., & Choudhury, S. (2020). Sustainable livelihood by HR capacity building in multi-cropping practices of Indian Eastern Himalayan region: A case study. *Journal of Statistics and Management Systems*, *23*(2), 277-284. http://dx.doi.org/10.1080/09720510.2020.1724626	Taylor & Francis	-	ESCI® (Web of Science) Australian Business Deans(ABDC)	Journal
3	Lalrochunga, D., Parida, A., & Choudhury, S. (2020). Sustainability of UAVs in developing countries: Prospects and challenges. *Journal of Discrete Mathematical Sciences and Cryptography*, *23*(1), 237-248. https://doi.org/10.1080/09720529.2020.1721887	Taylor & Francis	2.05	ESCI® (Web of Science) Australian Business Deans(ABDC)	Journal
4	Biman, P., Parida, A., Choudhury, S., & Chatterjee, S. (2019, December). Augmenting Farmer Producer Company through Aligning Indigenous Community Based Beliefs and Practices: Learnings from Abotani Community of Eastern Himalayan Region. In Proceedings of the 2nd International Conference on Information Systems & Management Science (ISMS). http://dx.doi.org/10.2139/ssrn.3511431	SSRN, Elsevier			Conference proceeding

5	Hatiboruah, J., Pant, R. M., & Choudhury, S. (2021). Reinforcing Livelihood by Interdependency of HR Capacity-ICT: Relevance to Multi-cropping practice system in Indian Eastern Himalaya. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012014). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012014	IOP Publishing	0.48	Scopus	Conference proceeding
6	Dash, S., Dash, K. K., & Choudhury, S. (2021). Evaluation of energy efficiency and moisture diffusivity for convective drying of large cardamom. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012016). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012016	IOP Publishing	0.48	Scopus	Conference proceeding
7	Dash, S., & Choudhury, S. (2021). Adopting Sustainable Farming: Implications of Renewable Energy and ICT. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012018). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012018	IOP Publishing	0.48	Scopus	Conference proceeding
8	Athira, R., Parida, A., & Choudhury, S. (2021). Significance of Renewable Energy for Empowering Cooperative-Farming Sector in Majuli Island of India. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1020, No. 1, p. 012021). IOP Publishing. http://dx.doi.org/10.1088/1757-899X/1020/1/012021	IOP Publishing	0.48	Scopus	Conference proceeding
9	R, Athira and Parida, Adikanda and Choudhury, Shibabrata, Proposed Cooperative Farming as a Catalyst to Livelihood Augmentation for the Marginal Farmers in Majuli Island (January 1, 2020). Proceedings of the 2nd International Conference on Information Systems & Management Science (ISMS) 2019 | Tripura University, Agartala, Tripura, India, Available at SSRN: https://ssrn.com/abstract=3512400 or http://dx.doi.org/10.2139/ssrn.3512400	SSRN, Elsevier			Conference proceeding

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ORIGINAL ARTICLE

Journal of Food Process Engineering WILEY

Energy and exergy analyses of solar drying of black cardamom (*Amomum subulatom* Roxburgh) using indirect type flat plate collector solar dryer

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Abstract

This study has summarized the energy and exergy analyses of flat plate collector solar dryer. The study involves a fundamental method for the design of the solar collector based on minimum entropy generation number (Ns) and mass flow number (M). The optimal performance parameters of the solar collector were determined using thermodynamic optimization procedure. Black cardamom was dried in the solar dryer at the drying air temperature range of 26–62°C. The amount of useful energy varied between 0.07 and 0.63 kW based on the degree of solar insolation. Subsequently, it was observed that the useful energy accumulated by the solar dryer was sufficient to dry black cardamom samples to 8.2% moisture content from an initial moisture content of 80.6%. The range of energy utilization values inside the cabinet was between 7.53 and 74.61 W for a period of 24 hr. It was observed that the energy utilization ratio (EUR) varied from 22.12–80.73%, 22.62–97.71%, and 14.25–77.81%, respectively, for the three consecutive days. The increase in the inlet air temperature led to an increase in the EUR values. Furthermore, during the drying studies, the exergy efficiency of the drying chamber was ranged from 31.19% to 93.28%, with an average of 72.08%. The developed solar dryer incorporates a free energy source, sustainability, increased drying capacity, and the creation of high-quality products. This dryer can be promoted as beneficial and sustainable equipment for drying agro products by small and marginal farmers.

Practical applications

Free energy sources and sustainability are the benefits of this solar dryer system. Agricultural producers are considering the use of renewable energy, such as solar energy, in the drying of agricultural goods. The design of the solar collector was based on the minimum entropy generation number. In this study, a dynamic model was provided in which the kinetics of moisture reduction are calculated based on the quantity of solar energy received in the collector and the temperature fluctuation in

Abbreviations & Symbols: A_c, collection area, m^2; $\dot{E}x$, $\dot{E}u$, exergy rate and energy utilization rate, $kJ\,s^{-1}$; EUR, energy utilization ratio, %; h, enthalpy, $kJ\,kg^{-1}$; $\dot{Q}$, Q, heat rate and net heat rate, $kJ\,s^{-1}$; S_{gen}, entropy generation rate, $W\,K^{-1}$; A_p, collector area, heat transfer area m^2; P, atmospheric pressure, kPa; $\dot{m}$, mass flow rate of air, $kg\,s^{-1}$; t, drying time, h; T, temperature, K; V, volume, m^3; v, velocity of dry air, $m\,s^{-1}$; U, internal energy, kJ; w, specific humidity, $g\,g^{-1}$; I_t, solar radiation, $W\,m^{-2}$; $\dot{T}$, apparent sun temperature, K; Q_A, solar radiation heat transfer, W; Q_{los}, heat loss to the ambient, W; T_p, outlet temperature of the solar air heater, K; N_S, entropy generation number; M, mass flow number; U_c, overall heat loss coefficient, $Wm^{-2}\,K^{-1}$; $\alpha\tau$, absorbance–transmittance product; η, exergetic efficiency, %; φ, relative humidity, %; θ, dimensionless temperature $= T/T_{amb}$; σ, solar air heater coordinate; Δ, difference in time; $\dot{m}_{wi}$, $\dot{m}_{wo}$, inlet and outlet humidity mass flow; $\dot{m}_{ai}$, inlet drying air mass flow; $\dot{m}_{ao}$, outlet drying air mass flow; $\dot{m}_{mp}$, mass flow rate of the moisture removed from the product on the tray; w_i, specific humidity (i: inflow, o: outflow, di: drying air at the inlet of the drying chamber); $\dot{E}u$, energy utilization rate; $P_{v,T}$, $P_{sat,T}$, partial vapour pressure at temperature T (v : partial vapor pressure, sat : saturated vapor pressure); Ex^R, exergy (R: reactive, N: nonreactive, PH: physical, KN: kinetic, PT: potential, CH: chemical).

the collector. The exergy input and exergy loss of the dryer are affected by solar radiation. The quantity of energy received and consumed is included in the energy analysis.

1 | INTRODUCTION

Black cardamom (*Amomum subulatom* Roxburgh) belongs to the family Zingiberaceae, and black cardamom is popular for its spice components. The black cardamom capsule contains phytochemicals that have anti-inflammatory and antibacterial properties. The essential oil obtained from the black cardamom has a distinctive characteristic flavor and has demonstrated several medicinal functions, including alexipharmic, stomachic, stimulant activities, and astringency. Therefore, black cardamom has been utilized for treating stomach torments and digestion related disorders (Bisht et al., 2011; Gautam et al., 2016). The composition of cardamom varies with the corresponding cultivar and stage of development of the capsule. Similarly, the composition is also affected by the region of cultivation and the corresponding climate of the region. The various components of the dried fruit of black cardamom include volatile oil (2.8–4.0%), protein (6%), starch (43%), ether (5%), and ash (4%; Gautam et al., 2016). Cardamom seeds are consumed in various forms, such as whole or powdered forms. It is one of the most valuable spices employed as an ingredient of curry powder, sausages, desserts, cakes, confectioneries, and beverages, such as coffee and tea.

Traditionally, cardamom curing was done using Bhatti, in which freshly harvested cardamom pods are dispersed on the drying platform and hot smokes produced from the firewood were passed through the layer of freshly harvested cardamom spread. However, in this case, constant attention is necessary to regulate temperature and maintain uniformity during drying (Lata, Mande, & Kishore, 2000). However, the fire produced during the traditional drying process is beyond control, leading to overheating, leading to a charred, smoky floured capsule with reduced volatile oil content. Generally, the conventional drying process can be as long as 48–72 hr and consume approximately 10 kg of firewood per 1 kg of dried black cardamom produced during the process (Seveda & Jhajharia, 2012). This reduces the final quality of volatile oil, rendering a low-quality product in the market. Hence, an alternate method of drying is essential for solving this problem.

Among different renewable energy sources, including geothermal, solar, and biomass, solar energy can be exploited and utilized worldwide, as geothermal sources are available at few locations and the supply of biomass is limited (Ehimen, 2016; Sampaio & González, 2017). Hence, these resources are not practically conducive for the respective applications. The intensity of solar flux passing through the earth's atmosphere is determined by several features. Some of the important factors include regional climate, corresponding latitude, geographic variation, and diurnal variation (Al-Tameemi & Chukin, 2016). Solar energy is one of the major potential alternatives for curbing the increasing demand for green energy. Drying using solar dryers is a modified version of the traditional sun drying technique, which has generally been employed to dry most agricultural commodities (Hii, Jangam, Ong, & Mujumdar, 2012). In comparison to sunlight-based drying, solar dryer maintains higher air temperatures, and significantly lower relative humidity, and hence improved drying rates can be achieved (Hossain & Bala, 2007). There are several reported studies on solar drying of fruits, vegetables, and plantation crops like blood fruit (Kondareddy et al., 2021), pineapple slices (Rani & Tripathy, 2021), turnips (Kong et al., 2021), and black peppers (Lakshmi, Muthukumar, & Nayak, 2021). Different types of solar dryers, including direct dryers, indirect and hybrid dryers, have been used and optimized to achieve the best drying conditions targeted towards maximum overall performance of the system. Solar drying was implemented in study of drying kinetics and properties of dried material in various products such as henna (Labed, Moummi, Aoues, & Benchabane, 2016), Algerian Deglet-Nour dates (Mennouche, Boubekri, Chouicha, Bouchekima, & Bouguettaia, 2017), carrot slices (Mahapatra & Tripathy, 2018), potatoes (Nasri & Belhamri, 2018), mint (Eltawil, Azam, & Alghannam, 2018; Moradi, Fallahi, & Mousavi Khaneghah, 2020), blackberry (López-Vidaña et al., 2019), mushroom slice (Babar, Tarafdar, Malakar, Arora, & Nema, 2020), and ivy gourd (Elangovan & Natarajan, 2021).

Initially, solar dryer was primarily employed to dry non-agricultural commodities; however, later, this process became a popular method being used for the drying of agricultural products. The studies on solar drying of wild coriander showed the highest retention of natural color and absence of browning in the dried coriander using an indirect solar dryer (Banout et al., 2010). During solar drying of gooseberry using forced convective solar dryer, samples treated through flaking preserved the highest concentrations of ascorbic acid (76.6%) attributed to the reduced sample exposure to the drying air (Verma & Gupta, 2004). Solar greenhouse drier constructed for vanilla pods yielded the export-quality product (standard Grade A) containing 2.36% of vanillin, where the average time of drying of vanilla pods varied between 49 and 53.5 hr and the drying temperature ranged between 33 and 65°C along with relative humidity of about 34% during the day (Abdullah & Mursalim, 1997). Apart from the major edible food commodities, recently, solar drying techniques and equipment have been increasingly employed for the drying and value addition of several agricultural and food industry byproducts and wastes (Galliou, Markakis, Fountoulakis, Nikolaidis, & Manios, 2018; Mghazli et al., 2017).

The performance of the solar drying systems was investigated using the energy and exergy approaches. Different agricultural products were subjected to energy and exergy analyses in an indirect solar drier with forced and natural convection (Hatami, Payganeh, &

Mehrpanahi, 2020; Mugi & Chandramohan, 2021). Several studies were conducted on the energy and exergy analyses of the solar drying of several commodities, such as mulberry, mint leaves, tomato, jackfruit leather, pistachio, coriander, red chili, and biomass targeted for other applications such as fuel, manure, and feed production (Akbulut & Durmuş, 2010; Akinola & Fapetu, 2006; Akpinar, 2010; Bagheri, Arabhoseini, & Kianmehr, 2015; Boulemtafes-Boukadoum & Benzaoui, 2011; Celma, Cuadros, López-Rodríguez, 2012; Chowdhury, Bala, & Haque, 2011; Fudholi et al., 2014; Midilli & Kucuk, 2003; Mugi & Chandramohan, 2021; Panwar, 2014; Sami, Etesami, & Rahimi, 2011; Tiwari & Tiwari, 2017). Energy analysis of a system is conducted using the first law of thermodynamics and is predominantly based on the quantity of energy in the system. However, it is commonly difficult to measure the precise value of energy associated with a system. Hence, in most solar energy-based systems, the primary criterion of energy analysis is change of energy (Dincer & Rosen, 2012). The exergy analysis of a system is useful for understanding the origin, position, and magnitude of various irreversibility leading to the decrease in the overall efficiency of the system. Other studies had also reported the impact of different factors, including solar radiation, inlet temperature, mass flow rate and time, on exergetic performance of the respective systems, where it has been further observed that the intensity of solar radiations significantly and recurrently affect the energy and exergy efficiencies (Sansaniwal, Sharma, & Mathur, 2018). Hence, in the view of the literature study conducted during this project and the research gap in energy and exergy analyses of solar drying of aromatic commodities such as black cardamom, the following objectives were considered. The objective of this research was to design a solar dryer for drying black cardamom in order to produce a high-quality product. The energy and exergy analysis was performed to ensure the economic viability of the solar drying process.

2 | MATERIALS AND METHODS

2.1 | Materials

The fresh black cardamom (*A. subulatum*) samples were obtained from a local farm located in Itanagar, Arunachal Pradesh, India. Grading of cardamom was done on the basis of their size and color. Dark colored (brownish-red color) capsules were chosen for the drying experiment. The freshly harvested cardamom capsules had a moisture content (MC) of 80.56 ± 1.48% (wet basis). The MC of the fresh black cardamom was evaluated by dehydrating the sample in the vacuum oven at temperature 105°C for a period of 6 hr (AOAC, 1999).

2.2 | Design of the solar collector

According to the entropy generation minimization theorem, the work lost or not available in a system is defined in Equation (1).

$$W_{\text{lost}} = T_o S_{\text{gen}} \quad (1)$$

where T_o represent the system's reference temperature, S_{gen} represents the variation in entropy generated with time.

Minimizing entropy generation (S_{gen}) in this approach entails minimizing lost or unavailable work. In other words, reducing entropy generation makes the system less irreversible and, as a result, thermodynamically optimum. Consequently, limiting the entropy produced by a solar collector is equivalent to optimizing its exergy flow. Due to this minimum entropy generation concept was applied for the design of solar collectors.

The solar collector was designed based on the second law of thermodynamics and was referred to the graphical determination of the entropy generation number *N*, where the designs of solar air heaters were developed to achieve minimum entropy generation. This approach has been observed to be convenient for the determination of the optimal operating conditions of the solar collector, including optimal mass flow rate for fixed collector area and the collection area for achieving the optimal outlet air temperature for a particular mass flow rate (Torres-Reyes, Cervantes-de Gortari, Ibarra-Salazar, & Picon-Nunez, 2001).

Torres-Reyes et al. (2001) have discussed in detail the use of "N" and the criterion for the optimum thermodynamic activity of a solar collector under non-isothermal, finite-time conditions. The heat loss to the ambient at ambient temperature during heating of air inside the solar collector (Q_{los}) and the solar radiation heat transfer (Q_A) were evaluated using Equations (2.1) and (2.2) (Table 1). The total rate of entropy generation was assessed, wherein the entropy generated during a process (S_{gen}) was a positive quantity or zero for a reversible process. In a non-isothermal solar energy collector with area A_p operating at temperature *T*, the total rate of entropy generation ($\dot{S}_{\text{gen}}$) was obtained by using Equations (2.4) to (2.7) (Table 1). A thermodynamic process proceeds in the chamber that conforms to the increase of principle entropy ($S_{\text{gen}} > 0$). The entropy generation rate is a function of mass flow number and collector outlet temperature. The correlation between these variables (mass flow number and maximum solar collector temperature) can be obtained by integrating the steady state energy balance at any point on the surface "A_p" of a solar air heater assuming local thermal equilibrium between the solar air heater surface and the air. The optimum design of the solar dryer was concluded as achieved when the system operated with the minimum loss of useful work along with minimal entropy generation. The optimal design was formulated based on entropy generation number "Ns" (Equations (2.8) and (2.9)) and the mass flow number, M (Equations (2.9)–(2.13)), which correspond to the optimum collection of solar energy and optimum flow of working fluid, respectively (Table 1).

2.3 | Experimental setup of the solar dryer

The schematic diagram of the laboratory solar dryer is presented in Figure 1. The experimental setup consisted of four main elements, which included (i) solar collector, (ii) drying chamber, (iii) exhaust,

TABLE 1 Relations correlating total rate of entropy generation, entropy generation number and mass flow number

Parameter	Equation	Equation no.
Q_{los}	Heat loss to the ambient at ambient temperature Q_{los} $Q_{los} = Q_A - m\,Cp\,(Tout - T_{in})$ $w_i = w_{amb}; T_{ai} = T_{amb}; \varphi_{ai} = \varphi_{amb}; h_{ai} = h_{amb}$ $w_{di} = w_o; T_{di} = T_o; \varphi_{di} = \varphi_o; h_{di} = h_{ao}$	2.1
Q_A	The solar radiation heat transfer $Q_A = (\alpha\tau) I_t A_c$	2.2
θ	Dimensionless temperature θ $\theta = \frac{T}{T_{amb}}$	2.3
$\dot{S_{gen}}$	The total rate of entropy generation $\dot{S_{gen}} = m\,Cp\,ln\frac{T_{out}}{T_{in}} - \frac{Q_A}{T_a} + \frac{Q_{los}}{T_{amb}}$	2.4
	$\dot{S_{gen}} = m\,Cp\,\ln\frac{T_{out}}{T_{in}} - \frac{Q_A}{T} + \frac{Q_A - m\,Cp\,(Tout - T_{in})}{T_{amb}}$	2.5
	$\dot{S_{gen}} = m\,Cp\,\ln\frac{T_{out}}{T_{in}} - \frac{(\alpha\tau) I_t A_c}{T} + \frac{(\alpha\tau) I_t A_c - m\,Cp\,(Tout - T_{in})}{T_{amb}}$	2.6
	$\frac{\dot{S_{gen}} T_{amb}}{(\alpha\tau) I_t A_c} = \frac{m\,Cp\,T_{amb}}{(\alpha\tau) I_t A_c}\left(\ln\frac{\theta_{out}}{\theta_{in}} - \theta_{out} + \theta_{in}\right) - \frac{1}{\theta} + 1$	2.7
N_S	Entropy generation number $N_S = \frac{\dot{S_{gen}} T_{amb}}{(\alpha\tau) I_t A_c}$	2.8
	$N_S = \frac{m\,Cp\,T_{amb}}{(\alpha\tau) I_t A_c}\left(\ln\frac{\theta_{out}}{\theta_{in}} - \theta_{out} + \theta_{in}\right) - \frac{1}{\theta} + 1$	2.9
M	Mass flow number M $M = \frac{mCp\,T_{amb}}{(\alpha\tau) I_t A_c}$	2.10
	$N_S = f(M, \theta_{out})$ $N_S = M\left(\ln\frac{\theta_{out}}{\theta_{in}} - \theta_{out}\right) + \theta_{in} - \frac{1}{\theta} + 1$	2.11
	Steady-state energy balance Equation. On the surface of solar collector $G\frac{A_c}{A_p}(\alpha\tau) = Uc(T - T_{amb}) + \dot{m}Cp\frac{dT}{dx}$	2.12
	Mass flow number as a function of θ_{max} $M = \frac{\dot{m}\,Cp\,T_{amb}}{(\alpha\tau) I_t A_c} = \frac{1}{(\theta_{max} - 1)} \frac{1}{\ln[(\theta_{max} - \theta_{in})/\theta_{max} - \theta_{out}]} = \left[(\theta_{max} - 1)\ln\frac{(\theta_{max} - \theta_{in})}{\theta_{max} - \theta_{out}}\right]^{-1}$	2.13
θ_{max}	Maximum collector temperature or sun–air temperature θ_{max} $\theta_{max} = 1 + \frac{(\alpha\tau) I_t A_c}{U_c A_p T_{amb}}$	2.14

Note: $\dot{S_{gen}}$ = the total rate of entropy generation, $m\,Cp\ln\frac{T_{out}}{T_{in}}$ = non-isothermal heat transfer to the working fluid between inlet and outlet, m = mass flow rate of air in kg s^{-1}, c_p = specific heat in kJ kg K^{-1}, T_{out} = outlet flow temperature in K, T_{in} = inlet flow temperature in K, T_a = apparent Sun temperature in K, T_{amb} = ambient temperature in K, Q_A = the solar radiation heat transfer, Q_{los} = the heat loss to the ambient at a temperature T_{amb}, I_t = solar radiation in W m^{-2}, A_c = Solar radiation collection area in m^2, A_p = heat transfer area of the collector in m^2, α = absorbance of product, τ = transmittance of product, N_S = entropy generation number, M = mass flow number, U_c = overall heat loss coefficient in W m^{-2}·K^{-1}, θ_{max} = maximum collector temperature or sun–air temperature.

and (iv) data logger. During the solar drying process, the ambient air was heated up to a certain temperature through the solar air collector, and afterward, it was passed to the drying chamber. The drying chamber was made of galvanized iron material. The drying chamber had insulated layers of polyurethane also. The drying cabinet had two aluminum trays in between the top and bottom surface of the drying chamber, and the vertical spacing between two consecutive trays was 20 cm. The hot, humid air released after drying was passed to the exterior through the chimney provided on top of the drying chamber. The various components of the solar dryer were connected through foam-insulated PVC pipe. The entire system was completely instrumented, and a special allowance was included in calculating the properties of solar radiation and environmental parameters. The drying experiments were performed in the designed solar dryer to determine the output parameters at various air mass flow rates.

2.4 | Experimental procedure

The solar drying experiments were conducted on a regular basis from 8:00 a.m. to 4:00 p.m. for three consecutive days starting at 8:00 a.m. to 4:00 p.m., during March 2021 (Latitude 25.0108° N and Longitude 88.1411° E). During the experiment, the air temperature at the input and output of the solar collector and the drying chamber was measured using a k-type thermocouple. Based on the measured partial vapor pressure of water, web bulb temperature, and dry bulb temperature of air the various psychrometric properties such as relative humidity, specific humidity, and enthalpy were evaluated (Table 2). Solar insolation on the surface of the collector was obtained by a pyranometer (SP-110 Pyranometer). An anemometer was used to monitor the flow rate of air at the solar collector inlet. All the thermocouples and pyranometer were linked to a data logger to record the measured temperature and solar insolation data at regular time

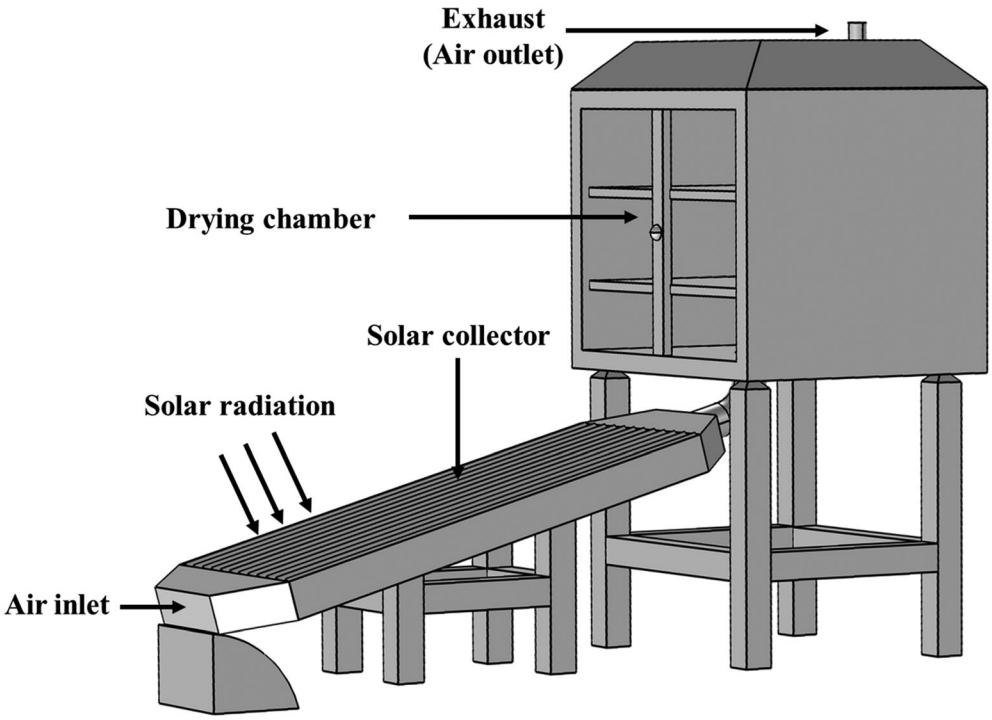

FIGURE 1 Experimental setup of flat plate collector solar dryer for drying of black cardamom

TABLE 2 Psychometric correlations for energy and exergy analysis

Term	Symbol	Formulae
Relative humidity	R_H	$R_H = \frac{P_{v,T}}{P_{sat,T}}$ $P_{v,T}$ is the partial vapor pressure of water in the mixture at a given temperature, $P_{sat,T}$ is the saturated vapor pressure at the same temperature.
Specific humidity	w	$w = 0.622\,\frac{P_{v,T}}{P - P_{v,T}}$
Enthalpy	h_{ai}	$h_{ai} = Cp_{ai}T_{ai} + wh_{sat,T}$

intervals. The obtained values were further used for energy and exergy analysis.

2.5 | Drying kinetics by using the Weibull model

The wet basis and dry basis MC of black cardamom at various time intervals during drying was estimated by using Equation (3).

$$M_t = \frac{m_i - m_f}{m_f} \times 100 \tag{3}$$

where m_t represented the dry basis MC of the product in % at time t, m_i, and m_f represented the initial weight prior to drying and final weight after drying (g), respectively.

The dimensionless moisture ratio during solar drying of black cardamom was evaluated by using Equation (4) (Erenturk, Gulaboglu, & Gultekin, 2004).

$$\mathrm{MR} = \frac{M_{t-M_\infty}}{M_{o-M_\infty}} \tag{4}$$

The sunlight drying and solar drying of black cardamom capsules was modeled by using Weibull distribution. The two-parameter formulation of Weibull distribution was usually implemented to represent the drying of porous plant materials. The two-parameter Weibull probability density function is presented in Equation (5).

$$MR = \frac{M_{t-M_\infty}}{M_{o-M_\infty}} = \exp\left[-\left(\frac{t}{\alpha_w}\right)^{\beta_w}\right] \tag{5}$$

where α_w represented the scale factor and β_w represented the shape parameter. When the value of β_w is equal to 1 the Weibull reduces to an Exponential distribution. The experimental data obtained at different intervals of time during the drying process was fitted with the Weibull model. The suitability of the model to represent the sun and solar drying of black cardamom was selected based on the root mean square deviation (RMSE), reduced chi-square (χ^2), and coefficient of determination (R^2) value (Raj & Dash, 2020). The model with minimum RMSE and χ^2 value and maximum R^2 value was denoted as the best suitable model to describe the drying process.

2.6 | Determination of effective moisture diffusivity

The drying characteristic of food is generally described by effective moisture diffusivity. The moisture movement during solar drying is a complex process involving molecular diffusion, capillary flow, hydrodynamic flow, surface diffusion, and all other factors. Fick's second

law can be used to estimate and define effective diffusivity when all of these factors are considered together.

The necessary assumptions for the analytical solution of Fick's second law of unsteady-state mass transfer are (i) Shrinkage is negligible, (ii) Moisture transfer is unidirectional, (iii) Uniform distribution of moisture during the initiation of drying process, and (iv) Diffusion coefficient of moisture is constant.

Assuming black cardamom is spherical in shape, the mathematical solution of this model is presented in Equation (6) (Crank, 1975).

$$MR = \frac{M_{t-M_\infty}}{M_{o-M_\infty}} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(-\frac{(2n+1)^2 \pi^2 D_{eff}\, t}{L^2}\right) \quad (6)$$

where, D_{eff} represented the effective moisture transfer diffusion coefficient for the drying process (m^2/s), L represented the characteristic length, and t represented the time of drying for the solar drying of black cardamom.

2.7 | Energy analysis for the solar drying process

The solar drying process involves the combination of both heat and mass transfer through which the moisture present in the product was removed. The energy needed for solar drying is mainly influenced by product type and rate of drying. The solar collector acts as a heat exchanger that turns incident solar energy into heat energy and eventually transfers the heat to the working fluid air. Solar air heating is defined as a process by which heat is supplied from a solar collector through which air circulates. Energy analysis was performed to quantify the energy required to dry black cardamom in the designed solar dryer. Energy analysis using solar energy based on mass balance for hot air in a steady state is presented in Equation (7).

$$\sum \dot{m}_{ai} = \sum \dot{m}_{ao} \quad (7)$$

The mass balance of moisture during drying is shown in Equation (8).

$$\sum (\dot{m}_{wi} + \dot{m}_{mp}) = \sum \dot{m}_{wo} \quad (8)$$

The general equation for energy conservation is presented in Equation (9)

$$\dot{Q} - \dot{E}u = \sum \dot{m}_{ao} \left(h_{ao} + \frac{{v_{ao}}^2}{2}\right) - \sum \dot{m}_{ai} \left(h_{ai} + \frac{{v_{ai}}^2}{2}\right) \quad (9)$$

The conditions of inlet air into the solar collector were considered equivalent to the ambient conditions. The difference in the radiation level absorbed by the collector and the heat energy lost by the collector was represented as useful energy. The useful energy gain by air of solar air collector during the process is presented in Equation (10)

$$\dot{Q}_u = \dot{m}_{ai}\, Cp_{ai}\, (T_{ao} - T_{amb}) \quad (10)$$

The heat used within the drying chamber is presented in Equation (11).

$$\dot{Q}_d = \dot{m}_a\, (h_{di} - h_{do}) \quad (11)$$

The energy utilization ratio (EUR) value was implemented as an indicator of the performance of the drying cabinet. EUR was evaluated based on dry-bulb temperature and enthalpy values using Equation (12).

$$EUR_d = \frac{\dot{m}_a\, (h_{di} - h_{do})}{\dot{m}_a\, Cp_a\, (T_{di} - T_{amb})} \quad (12)$$

2.8 | Exergy analysis of the drying chamber

The exergy content of the system was evaluated utilizing the conservation of the principles of mass and energy together based on three parameters such as (i) total exergy inflow to drying chamber, (ii) total exergy outflow of the drying chamber, and (iii) exergy losses of the drying chamber.

The exergy output of the system comprises four types of exergy such as (i) physical or flow (Ex^{PH}), (ii) kinetic (Ex^{KN}), (iii) potential (Ex^{PT}), and (iv) chemical (Ex^{CH}) exergy.

The generalized model for the total exergy of a given framework is presented in Equations (13) and (14)

$$Ex_{sys} = Ex^{PH} + Ex^{KN} + Ex^{PT} + Ex^{CH} \quad (13)$$

$$Ex_{sys} = (U - U_0) + p_0(V - V_0) - T_0\,(S - S_0) + \frac{1}{2} mv^2 + mgz + Ex^R + Ex^N \quad (14)$$

The changes in potential and kinetic exergies were neglected, and the pressure changes in the framework were ignored, as V = V_o. The Equation (14) was translated into Equation (15) as shown below.

$$\dot{Ex} = \dot{m}_a\, Cp_a \left[(T - T_{amb}) - T_{amb} \ln \frac{T}{T_{amb}}\right] \quad (15)$$

Depending on the inlet and outlet temperatures of the drying chamber, the exergy inflow and outflow was expressed according to Equations (16) and (17).

$$\dot{Ex}_{di} = \dot{m}_i\, Cp_{ai} \left[(T_{di} - T_{amb}) - T_{amb} \ln \frac{T_{di}}{T_{amb}}\right] \quad (16)$$

$$\dot{Ex}_{do} = \dot{m}_i\, Cp_{ai} \left[(T_{do} - T_{amb}) - T_{amb} \ln \frac{T_{do}}{T_{amb}}\right] \quad (17)$$

In Equation (16), exergy inflow ($\dot{Ex}_{di}$) is a function of inlet temperatures of the drying cabinet and in Equation (17) exergy outflow ($\dot{Ex}_{do}$) is a function of outlet temperatures of the drying cabinet. The difference between the inflow and outflow exergy was represented as the exergy loss and was evaluated using Equations (18) and (19).

$$\text{Exergy loss} = \text{Exergy inflow} - \text{Exergy outflow} \tag{18}$$

$$\dot{Ex}_L = \dot{Ex}_{do} - \dot{Ex}_{di} \tag{19}$$

The exergetic efficiency was depicted as the proportion of the exergy outflow to exergy inflow and was evaluated using Equation (20).

$$\eta = 1 - \frac{\dot{Ex}_L}{\dot{Ex}_{di}} \tag{20}$$

3 | RESULTS AND DISCUSSION

3.1 | Optimal surface area of the solar collector

The relation between maximum collector outlet temperature and thermal conductance per unit time of collection area $U_c(A_p/A_c)$ for different solar radiations are presented in Figure 2. It was observed that the maximum value of thermal conductance per unit time of collection area $U_c(A_p/A_c)$ was recorded at solar radiation of 900 W/m^2. The total rate of entropy generation "N_s" was evaluated by using Equations (2.1)–(2.9) and mass flow number "M" was assessed by using Equations (2.10)–(2.13). Figure 3 shows N_s as a function of maximum outlet temperature θ_{max} (Equation (2.14)) at different outlet temperatures θ_{out} of the air inside the collector. The data from the analysis presented in this figure was applied in experiments for drying black cardamom under four different mass flow rates. The results showed that an increase in the mass flow rate of air decreased the Ns value. Determination of the optimal area of the present solar collector was based on the procedure formulated by Torres-Reyes et al. (2001) for minimum entropy generation, as this was the most appropriate formula for the present collector type. Depending on minimum entropy generation number Ns, the collection area for rectangular projection of solar collector was determined as 2.64 m^2. Figure 4 depicts the results of the mass flow number of the solar collector as a function of outlet temperature of the air, for different dimensionless

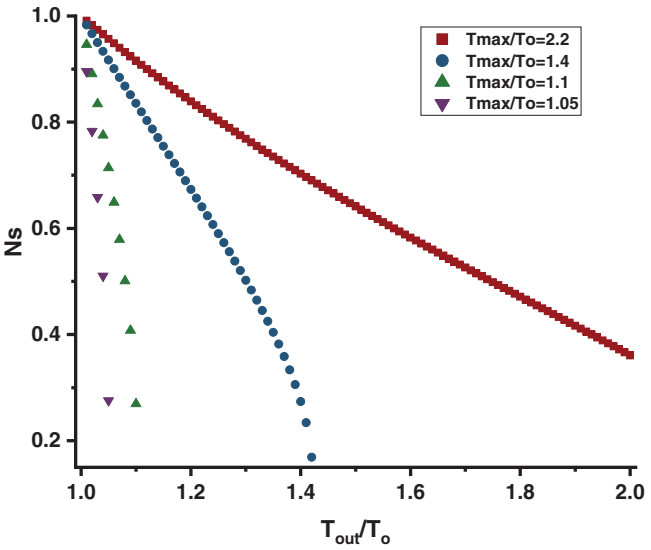

FIGURE 3 Entropy generation number N_s of the solar collector as function of required outlet temperature of air at various dimensionless maximum collector temperature

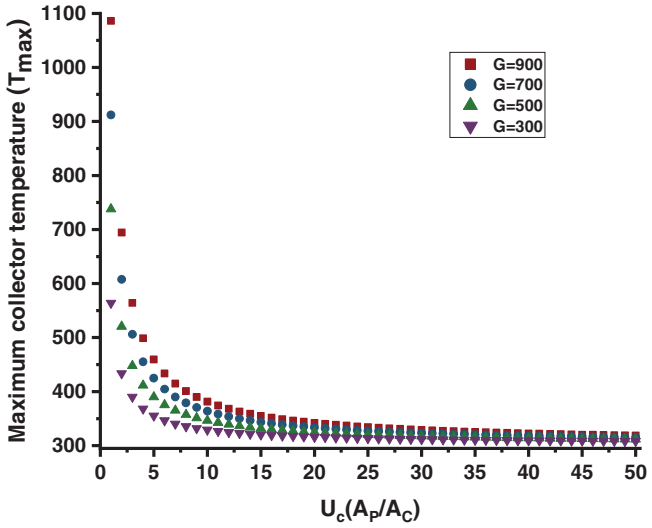

FIGURE 2 Sun–air temperature of a solar collector as a function of conductance per collection area $U_c(A_p/A_c)$, for different incident solar radiation values at $T_{amb} = 30°C$

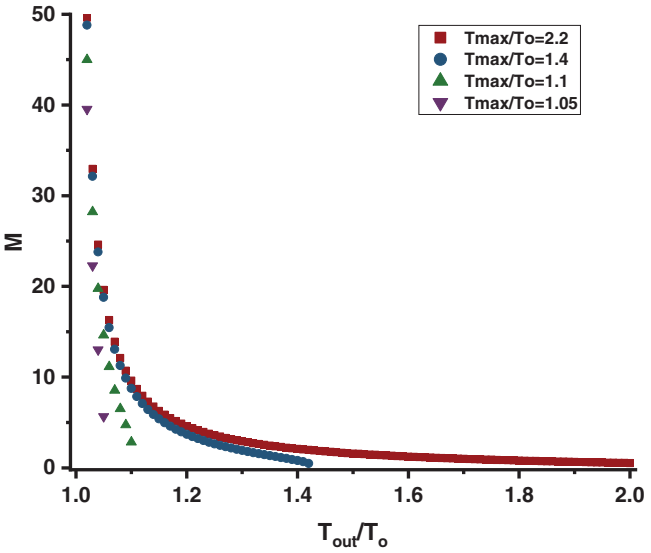

FIGURE 4 Mass flow number M of the solar collector as a function of outlet temperature of the air at various dimensionless maximum collector temperature

maximum collector temperatures (θ_{max}). The graph was subsequently used to find the optimal flow rate for a given, fixed collector area. Four different values for θ_{max} were considered (1.05, 1.1, 1.4, and 2.2), and the results showed that optimal mass flow rate varied between 0.016 and 0.019 kg/s for the $A_c = 2.64\,m^2$. Based on the minimum entropy generation number (Ns) and mass flow number (M), a solar collector with $A_c = 2.64\,m^2$ and an air mass flow rate of 0.018 kg/s was selected.

Accordingly, a flat plate solar collector of external dimensions $220 \times 120 \times 32\,cm^3$ was fabricated. The main components of the solar air collector consisted of a cover layer, the base plate, and the absorber plate. An aluminum sheet of thickness 1 mm was used as the absorber plate, and the surface of the aluminum sheet was coated with black paint. The absorber plate was covered with a 5 mm thick, toughened transparent glass (made by Saint Gobain), which acted as a cover plate. The coefficients of emissivity and transmission of the cover plate were 94 and 81%, respectively (Bouadila, Lazaar, Skouri, Kooli, & Farhat, 2014). The absorber plate was fitted in the box 75 mm away from the cover plate. The setup of the collector was mounted on a suitably built MS angle frame. To optimize the accumulation of solar radiation and ensure supply of air into the drying chamber, the collector was directed at a local latitude of 26.8° toward the south direction. The collector was insulated with a polyurethane layer (heat conductivity 0.028 W/m K) with a thickness of 15 mm on both sides and at the bottom surface.

3.2 | Variation of solar radiation and solar collector outlet temperature during drying

The experimental model described in the previous section of the solar dryer was tested with black cardamom during the present study. Experiments were carried out for 3 consecutive days, starting at 8:00 a.m. to 4:00 p.m., during March 2021. Figure 5 shows the plot of solar radiation measured, ambient air temperature recorded, and solar collector outlet temperature versus drying time. Solar radiation values during the experiment ranged from 417.43 to 801.11 W/m^2 on the first day, 393.97 to 812.61 W/m^2 on the second day, and 430.57 to 832.11 W/m^2 on the third day. The ambient air temperature varied from 20.6 to 28.6°C, 21.6 to 29°C, and 22 to 29°C on the first, second, and third day, respectively.

The break between the curves indicated the night duration. It was observed that the solar radiation increased in the first 4 hr, reached a maximum value at 12:00–01:00 p.m., and then gradually decreased. The highest value of solar radiation recorded was 801.11, 812.6, and 832.1 W/m^2 for the 3 consecutive days. Similar trends were observed with the ambient air temperature values. The maximum ambient air temperature values documented for 3 days were 28.6, 29.0, and 29.5°C, respectively. The highest values of the ambient air temperature were recorded at 01:00 p.m. The outlet temperature increased linearly as the amount of solar energy increased during the day. At a solar irradiation level of 801.11 W/m^2, the maximum air temperature of the solar collector outlet was reported as 62°C for an input air temperature of 27°C. The maximum temperature gain in the collector during the peak afternoon period (1:00 p.m.) on all days was around 59°C (varying between 62 and 58°C). The outlet temperature of the solar collector during 3 days varied from 30–62°C, 26–58°C, and 29–58°C, respectively, at the mass flow rate of 0.018 kg/s.

3.3 | Moisture content variation during solar drying of black cardamom

The decrease in MC (dry basis) of black cardamom as a function of drying time in a solar dryer is depicted in Figure 6. In this study, $t = 0$ in elapsed drying time axis corresponds to MC at 8:00 a.m. on the first

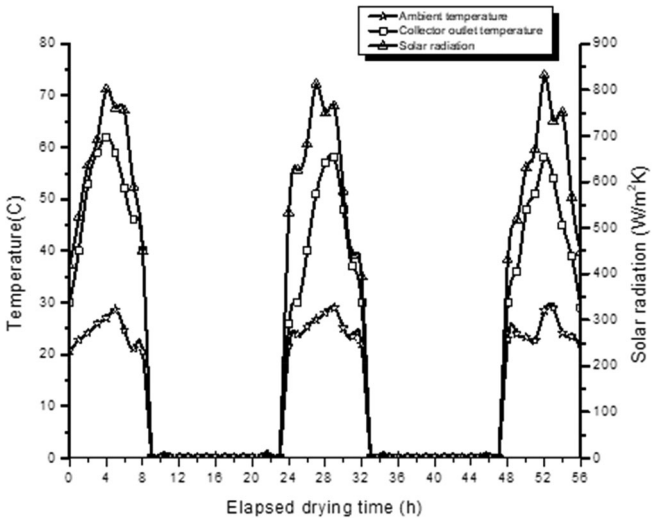

FIGURE 5 Solar radiation, ambient air temperature, and solar collector outlet air temperature versus elapsed drying time

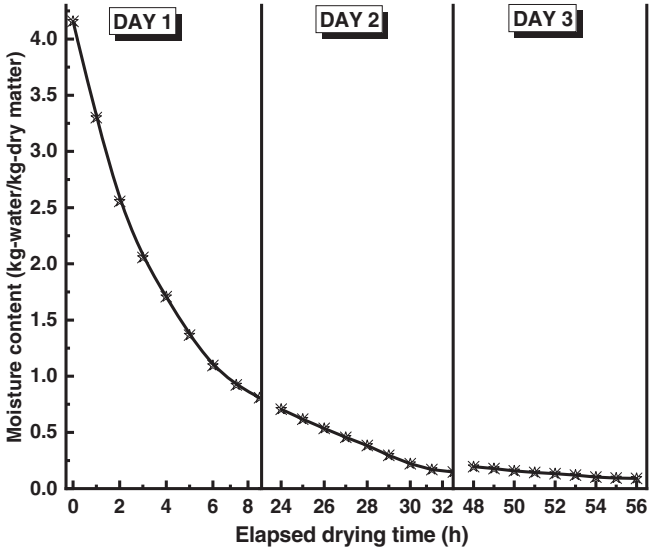

FIGURE 6 Changes in moisture content of black cardamom with respect to drying time during the solar drying process

day. The freshly harvested black cardamom was dried to 8.2% (wb) MC from an initial MC of 80.6% (wb) within 24 hr drying period. It was observed that the MC decreased with drying time at a constant airflow rate of 0.018 kg/s. The drop in MC was faster in the first 8 hr of drying than in the next 2 days. It was observed that when the ambient air temperature increased, the relative humidity of the air declined to a minimum of 45% at 01:00 p.m. Hence, the faster drying rates were observed for increased ambient air temperature due to the corresponding increase in the solar insolation intensity. Figure 6 depicts the decrease in MC (dry basis) of black cardamom as a function of drying time in a solar dryer (6). $T = 0$ in the elapsed drying time axis corresponds to MC at 8:00 a.m. on the first day in this study. Within 24 hr, freshly harvested black cardamom was dried to 8.2% (wb) MC from an initial MC of 80.6% (wb). At a constant airflow rate of 0.018 kg/s, the MC decreased with drying time. The drop in MC was quicker in the first 8 hr of drying than in the next 2 days. It was discovered that when the ambient air temperature increased, the relative humidity of the air declined to a minimum of 45% at 01:00 p.m. As the MC of the sample in the solar dryer declined, so did the moisture diffusion from the cardamom to the surroundings. Cardamom weight loss was initially faster due to unbound water on the outside surface but eventually slowed due to internal moisture migration from the interior layers to the surface. Solar drying of black cardamom drying followed a period of declining rates, that is, falling rate period. A study on solar drying of *Valeriana jatamansi* using a forced convection solar dryer integrated with phase change material revealed that the drying rate was faster at the initial stage and then decreased significantly as drying time progressed (Bhardwaj, Chauhan, Kumar, Sethi, & Rana, 2017). This is consistent with the experimental data obtained during the solar drying of black cardamom.

3.4 | Drying kinetics and diffusivity study during solar drying of black cardamom

The drying kinetics study showed that the moisture ratio and drying rate dropped gradually with drying time in both direct sun drying and solar drying of black cardamom. The moisture ratio decreased rapidly in the early stages of drying, and in the later stages, the decrease of moisture ratio was slower. The volume of free water present in the freshly harvested black cardamom at the initiation of drying was very large. Hence, the rate of water removal was faster at the beginning of the drying phase. Shortly after the drying began, the moisture ratio continued to decrease. The water loss was accentuated up to a period of 25 hr in direct sun drying. Similarly, the loss of water was accentuated up to the time period of 18 hr in the solar drying process (Figure 6). This refers to a phase of higher moisture removal during which the rate of water migration to the surface is lower than the rate of evaporation, resulting in a continually drying surface for drying. The drying tends to be less significant with the advancement of time beyond 18 hr in the case of solar drying because evaporation from the interior of the food is completed. Also, during this stage, the MC decreases, and hence the heat and moisture transport pathways get more protracted and more tortuous. Toward the completion of the drying process, the drying rates were subjected to zero, as the removal of water became negligible. The moisture from the cardamom capsules dried in solar dyer evaporated more quickly than direct sun drying because of higher drying temperature in solar dyer. Therefore, the reduction of moisture ratio was faster in the case of the solar dryer. The experimental moisture ratio $\left(\frac{M_{t-M_\infty}}{M_{o-M_\infty}}\right)$ data were fitted to the Weibull model for modeling and predicting the drying kinetics of large cardamom and statistical parameters such as χ^2, R^2, and RMSE values were evaluated.

Direct sun drying and solar drying had coefficients of determination of 0.987 and 0.983, respectively. The χ^2 values for direct sun drying and solar drying were 2.027×10^{-3} and 0.591×10^{-3}, respectively, with RMSE values ranging from 1.401×10^{-2} to 2.369×10^{-2}. Accordingly, the Weibull model was found to be a good fit for predicting moisture ratio data of direct sun drying and solar drying of black cardamom. The values of scale parameter (α) and shape parameter (β) of the Weibull model for moisture ratio under various drying conditions were obtained by fitting Equation (5). The value of α for direct sun drying and solar drying was 840.39 ± 1.261 and 618.73 ± 1.509, respectively (min), and values of β were 0.797 ± 0.012 to 0.623 ± 0.027. The outcomes of the study revealed that both Weibull model parameters α and β were affected by the type of drying implemented. The scale parameter for moisture ratio was observed to be significantly lower ($p < .05$) in solar drying than in sun drying.

It was detected that D_{eff} values for solar drying are higher than those for direct sun drying. The Fick's diffusion model yielded effective moisture diffusivity (D_{eff}) values of 1.48×10^{-10} m^2/s for direct sun drying and 9.74×10^{-11} m^2/s for solar drying, respectively. Drying of black cardamom capsules in the solar dryer improved heating energy, which increased the interaction of water molecules, resulting in increased moisture diffusivity (Xiao et al., 2010). The D_{eff} values found for drying food items are in the typical range of $10^{-8} - 10^{-10}$ m^2/s (Zogzas, Maroulis, & Marinos-Kouris, 1996), and the D_{eff} attained in the solar drying of black cardamom was within this range.

3.5 | Energy analysis of thin layer solar drying

The variation of the energy utilization in the solar collector and drying chamber as a function of drying time is presented in Figure 7. The amount of useful energy from solar air collectors was determined using Equation (10) based on the inlet and outlet temperatures of the collector. The quantity of useful energy was found to vary between 0.07 and 0.63 kW depending on the degree of solar insolation. As a result, it was revealed that the useful energy generated from the solar air heater was adequate to dry a sample of black cardamom. Figure 7 depicts the variation of energy utilization inside the chamber on the right ordinate as a function of drying time. The values of energy utilization inside the cabinet were calculated using Equation (11). The MC of black cardamom within the chamber reduced from 80.6 to 8.2%

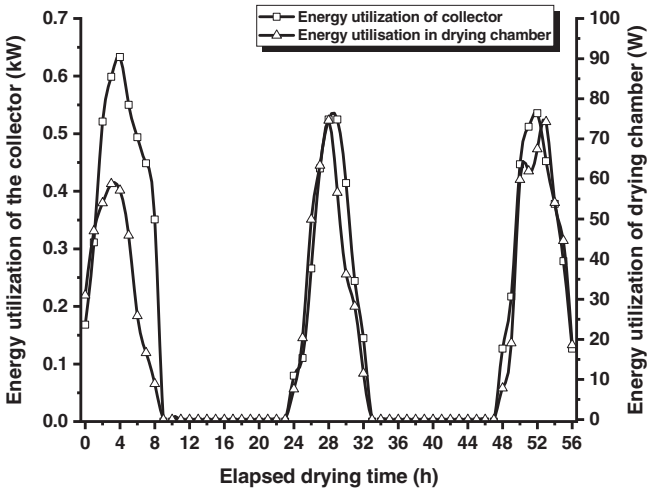

FIGURE 7 Changes in energy utilization of the collector and energy utilization of the drying chamber during drying of black cardamom

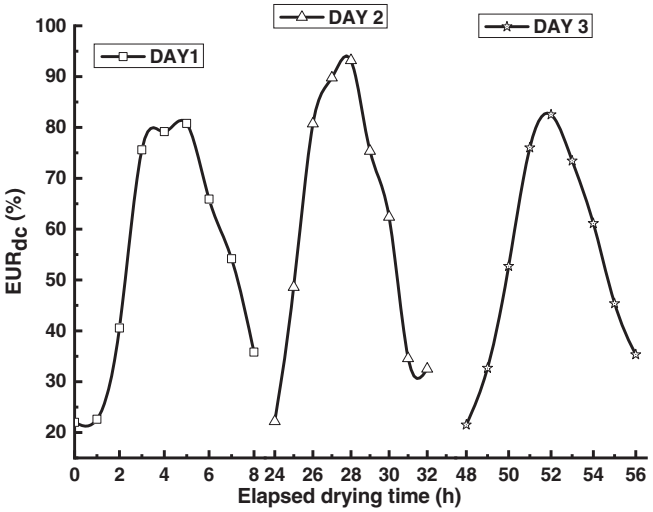

FIGURE 8 Changes in energy utilization ratio in drying chamber as a function of elapsed drying time during drying of black cardamom

(wb) with respect to the ranges of 7.5–74.61 W of energy utilization in 24 hr.

The energy utilization rate varies with the time of day, and this attains the peak value during midday, as the incident radiation on the collector is maximum at that time. As inlet temperature was ambient temperature, the temperature elevation inside the collector varied linearly along with the intensity and exposure to solar radiation. Karsli (2007) attained comparable findings in his work, where the study demonstrated the performance analysis of a flat plate solar collector based on the first and second laws of thermodynamics. The findings revealed that the effectiveness of a solar collector is affected by solar radiation and the collector's architecture.

Figure 8 depicts the assessment of the energy utilization ratio (EUR) of the drying process [computed using Equation (12)] as a function of drying time, which has been defined as the ratio of the energy

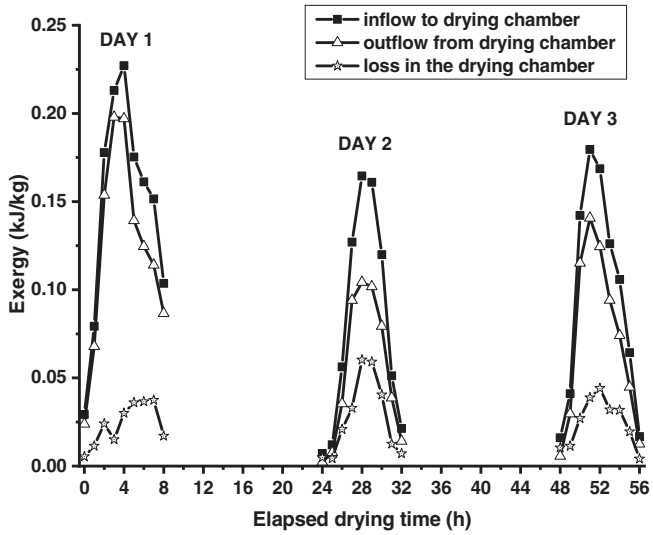

FIGURE 9 Exergy as a function of elapsed drying time during solar drying of black cardamom

utilization to the energy provided to the solar collector. For 3 days, the energy use values for the drying cycles were identical. It was observed that EUR varied from 22 to 80.7% during the first day of the experiment. The EUR varied from 22.6–97.7% and 14.2–77% on the second and third days, respectively. The energy utilization ratio was found to be higher on the second day, which may be ascribed to the structure, moisture content of the sample as well the conditions of the geographical location on that day. The EUR values increased as the temperature of the inlet air was increased. Celma and Cuadros (2009) produced similar results, illustrating the exergy efficiency of the drying chamber as a function of drying time. During the first 4.5 hr, a declining pattern was obtained, followed by a rising pattern and a pattern based on a parabolic function.

3.6 | Exergy analysis of thin layer solar drying

The exergy analysis of the thin layer drying process of black cardamom via flat plate collector solar dryer was performed using data obtained from the drying experiments conducted during the study. The evolution of exergy (inlet, outlet, and loss) with drying time has been represented in Figure 9. In the experiments performed during the 3 days, the exergy inflow, exergy outflow, and exergy loss in the drying chamber increased during the midday and after that showed a decreasing behavior. The maximum value of exergy inflow, exergy outflow, and exergy loss of the system was obtained as 0.22, 0.19, and 0.06 kW, respectively, during the 3 days. The exergy loss ranged from 0.005 to 0.03 kW, 0.004 to 0.06 kW, and 0.004 to 0.04 kW on the first, second, and third day, respectively. It was observed that variation in exergy loss appeared as a consequence of the fluctuations in solar radiation. On the second day of drying, the most exergy losses were obtained for the sun drying of black cardamom. Furthermore, the drying chamber's exergy efficiency ranged

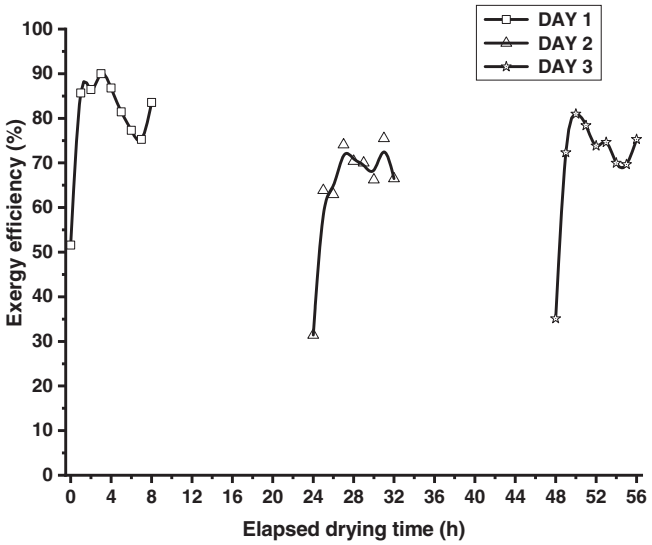

FIGURE 10 Exergy efficiency as a function of elapsed drying time during solar drying of black cardamom

from 31% to 93% during the studies, with an average of 72.08% (Figure 10).

4 | CONCLUSION

The black cardamom was dried in the flat plate collector solar dryer, and the energy and exergy studies of the drying process were conducted. The cardamom sample was sufficiently dried to obtain a final MC of approximately 0.09 kg water/kg dry matter at a mass flow rate of 0.018 kg/s. The energy consumption ratio is valuable for evaluating energy usage in the thin layer drying phase. As the energy consumption ratio (EUR) enhanced, the energy obtained from the solar collector was effectively used in the drying chamber. Exergy is a metric for energy efficiency, and it correctly represented the thermodynamic importance of solar drying. The higher exergy and lower thermal efficiency of the drying chamber demonstrated that a large amount of energy was wasted through the exhaust of the drying chamber. When exergy losses were lesser, the most effective use of exergy was accomplished. This indirect type flat plate collector solar dryer can be used in agricultural and agro-industry settings for drying spices such as chilies, coriander, pepper, and turmeric, as well as a variety of other applications that require hot air for drying.

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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REFERENCES

Abdullah, K., & Mursalim. (1997). Drying of vanilla pods using a greenhouse effect solar dryer. *Drying Technology*, *15*(2), 685–698.

Akbulut, A., & Durmuş, A. (2010). Energy and exergy analyses of thin layer drying of mulberry in a forced solar dryer. *Energy*, *35*(4), 1754–1763.

Akinola, A., & Fapetu, O. (2006). Exergetic analysis of a mixed-mode solar dryer. *Journal of Engineering and Applied Sciences*, *1*, 205–210.

Akpinar, E. K. (2010). Drying of mint leaves in a solar dryer and under open sun: Modelling, performance analyses. *Energy Conversion and Management*, *51*(12), 2407–2418.

Al-Tameemi, M. A., & Chukin, V. V. (2016). Global water cycle and solar activity variations. *Journal of Atmospheric and Solar-Terrestrial Physics*, *142*, 55–59.

Babar, O. A., Tarafdar, A., Malakar, S., Arora, V. K., & Nema, P. K. (2020). Design and performance evaluation of a passive flat plate collector solar dryer for agricultural products. *Journal of Food Process Engineering*, *43*(10), e13484.

Bagheri, H., Arabhoseini, A., & Kianmehr, M. H. (2015). Energy and exergy analyses of thin layer drying of tomato in a forced solar dryer. *Iranian Journal of Biosystem Engineering*, *46*, 39–45.

Banout, J., Havlik, J., Kulik, M., Kloucek, P., Lojka, B., & Valterova, I. (2010). Effect of solar drying on the composition of essential oil of sacha culantro (*Eryngium foetidum* L.) grown in the peruvian amazon. *Journal of Food Process Engineering*, *33*(1), 83–103.

Bhardwaj, A., Chauhan, R., Kumar, R., Sethi, M., & Rana, A. (2017). Experimental investigation of an indirect solar dryer integrated with phase change material for drying *Valeriana jatamansi* (medicinal herb). *Case Studies in Thermal Engineering*, *10*, 302–314.

Bisht, V., Negi, J., Bhandari, A., & Sundriyal, R. (2011). Amomum subulatum Roxb: Traditional, phytochemical and biological activities—An overview. *African Journal of Agricultural Research*, *6*(24), 5386–5390.

Bouadila, S., Lazaar, M., Skouri, S., Kooli, S., & Farhat, A. (2014). Energy and exergy analysis of a new solar air heater with latent storage energy. *International Journal of Hydrogen Energy*, *39*(27), 15266–15274.

Boulemtafes-Boukadoum, A., & Benzaoui, A. (2011). Energy and exergy analysis of solar drying process of mint. *Energy Procedia*, *6*, 583–591.

Celma, A. R., & Cuadros, F. (2009). Energy and exergy analyses of OMW solar drying process. *Renewable Energy*, *34*(3), 660–666.

Celma, A. R., Cuadros, F., & López-Rodríguez, F. (2012). Convective drying characteristics of sludge from treatment plants in tomato processing industries. *Food and Bioproducts Processing*, *90*(2), 224–234.

Chowdhury, M., Bala, B., & Haque, M. (2011). Energy and exergy analysis of the solar drying of jackfruit leather. *Biosystems Engineering*, *110*(2), 222–229.

Crank, J. (1975). *The mathematics of diffusion* (2nd ed.). London: Oxford University Press.

Dincer, I., & Rosen, M. A. (2012). *Exergy: Energy, environment and sustainable development*. Amsterdam: Elsevier.

Ehimen, E. (2016). Algae biomass supply chains. In J. Bo Holm-Nielsen & E. A. Ehimen (Eds.), *Biomass supply chains for bioenergy and biorefining* (pp. 319–332). UK: Elsevier.

Elangovan, E., & Natarajan, S. K. (2021). Effects of pretreatments on quality attributes, moisture diffusivity, and activation energy of solar dried ivy gourd. *Journal of Food Process Engineering*, *44*(4), e13653.

Eltawil, M. A., Azam, M. M., & Alghannam, A. O. (2018). Energy analysis of hybrid solar tunnel dryer with PV system and solar collector for drying mint (MenthaViridis). *Journal of Cleaner Production*, *181*, 352–364.

Erenturk, S., Gulaboglu, M. S., & Gultekin, S. (2004). The thin-layer drying characteristics of rosehip. *Biosystems engineering*, *89*(2), 159–166.

Fudholi, A., Sopian, K., Yazdi, M. H., Ruslan, M. H., Gabbasa, M., & Kazem, H. A. (2014). Performance analysis of solar drying system for red chili. *Solar Energy*, *99*, 47–54.

Galliou, F., Markakis, N., Fountoulakis, M., Nikolaidis, N., & Manios, T. (2018). Production of organic fertilizer from olive mill wastewater by combining solar greenhouse drying and composting. *Waste Management*, *75*, 305–311.

Gautam, N., Bhattarai, R. R., Khanal, B. K. S., & Oli, P. (2016). Technology, chemistry and bioactive properties of large cardamom (Amomum subulatum Roxb.): An overview. *International Journal of Applied Sciences and Biotechnology*, *4*(2), 139–149.

Hatami, S., Payganeh, G., & Mehrpanahi, A. (2020). Energy and exergy analysis of an indirect solar dryer based on a dynamic model. *Journal of Cleaner Production*, *244*, 118809.

Hii, C. L., Jangam, S. V., Ong, S. P., & Mujumdar, A. S. (2012). *Solar drying: Fundamentals, applications and innovations*. Singapore: TPR Group Publication.

Hossain, M., & Bala, B. (2007). Drying of hot chilli using solar tunnel drier. *Solar Energy*, *81*(1), 85–92.

Karsli, S. (2007). Performance analysis of new-design solar air collectors for drying applications. *Renewable Energy*, *32*(10), 1645–1660.

Kondareddy, R., Sivakumaran, N., Radha Krishnan, K., Nayak, P. K., Sahu, F. M., & Singha, S. (2021). Performance evaluation and economic analysis of modified solar dryer with thermal energy storage for drying of blood fruit (Haematocarpus validus). *Journal of Food Processing and Preservation*, *45*(9), e15653.

Kong, D., Wang, Y., Li, M., Liu, X., Huang, M., & Li, X. (2021). Analysis of drying kinetics, energy and microstructural properties of turnips using a solar drying system. *Solar Energy*, *230*, 721–731.

Labed, A., Moummi, N., Aoues, K., & Benchabane, A. (2016). Solar drying of henna (Lawsonia inermis) using different models of solar flat plate collectors: An experimental investigation in the region of Biskra (Algeria). *Journal of Cleaner Production*, *112*, 2545–2552.

Lakshmi, D. V. N., Muthukumar, P., & Nayak, P. K. (2021). Experimental investigations on active solar dryers integrated with thermal storage for drying of black pepper. *Renewable Energy*, *167*, 728–739.

Lata, K., Mande, S., & Kishore, V. (2000). *Studies on quality improvement of large-cardamom using an advanced gasifier based dryer*. New Delhi: Tata Energy Research Institute.

López-Vidaña, E. C., Pilatowsky Figueroa, I., Antonio Marcos, E. G., Navarro-Ocaña, A., Hernández-Vázquez, L., & Santiago-Urbina, J. A. (2019). Solar drying kinetics and bioactive compounds of blackberry (*Rubus fruticosus*). *Journal of Food Process Engineering*, *42*(4), e13018.

Mahapatra, A., & Tripathy, P. P. (2018). Modeling and simulation of moisture transfer during solar drying of carrot slices. *Journal of Food Process Engineering*, *41*(8), e12909.

Mennouche, D., Boubekri, A., Chouicha, S., Bouchekima, B., & Bouguettaia, H. (2017). Solar drying process to obtain high standard "deglet-nour" date fruit. *Journal of Food Process Engineering*, *40*(5), e12546.

Mghazli, S., Ouhammou, M., Hidar, N., Lahnine, L., Idlimam, A., & Mahrouz, M. (2017). Drying characteristics and kinetics solar drying of Moroccan rosemary leaves. *Renewable Energy*, *108*, 303–310.

Midilli, A., & Kucuk, H. (2003). Energy and exergy analyses of solar drying process of pistachio. *Energy*, *28*(6), 539–556.

Moradi, M., Fallahi, M. A., & Mousavi Khaneghah, A. (2020). Kinetics and mathematical modeling of thin layer drying of mint leaves by a hot water recirculating solar dryer. *Journal of Food Process Engineering*, *43*(1), e13181.

Mugi, V. R., & Chandramohan, V. P. (2021). Energy and exergy analysis of forced and natural convection indirect solar dryers: Estimation of exergy inflow, outflow, losses, exergy efficiencies and sustainability indicators from drying experiments. *Journal of Cleaner Production*, *282*, 124421.

Nasri, M. Y., & Belhamri, A. (2018). Effects of the climatic conditions and the shape on the drying kinetics, application to solar drying of potatocase of Maghreb's region. *Journal of Cleaner Production*, *183*, 1241–1251.

Panwar, N. (2014). Experimental investigation on energy and exergy analysis of coriander (Coriadrum sativum L.) leaves drying in natural convection solar dryer. *Applied Solar Energy*, *50*(3), 133–137.

Raj, G. B., & Dash, K. K. (2020). Microwave vacuum drying of dragon fruit slice: Artificial neural network modelling, genetic algorithm optimization, and kinetics study. *Computers and Electronics in Agriculture*, *178*, 105814.

Rani, P., & Tripathy, P. P. (2021). Drying characteristics, energetic and exergetic investigation during mixed-mode solar drying of pineapple slices at varied air mass flow rates. *Renewable Energy*, *167*, 508–519.

Sami, S., Etesami, N., & Rahimi, A. (2011). Energy and exergy analysis of an indirect solar cabinet dryer based on mathematical modeling results. *Energy*, *36*(5), 2847–2855.

Sampaio, P. G. V., & González, M. O. A. (2017). Photovoltaic solar energy: Conceptual framework. *Renewable and Sustainable Energy Reviews*, *74*, 590–601.

Sansaniwal, S. K., Sharma, V., & Mathur, J. (2018). Energy and exergy analyses of various typical solar energy applications: A comprehensive review. *Renewable and Sustainable Energy Reviews*, *82*, 1576–1601.

Seveda, M., & Jhajharia, D. (2012). Design and performance evaluation of solar dryer for drying of large cardamom (Amomum subulatum). *Journal of Renewable and Sustainable Energy*, *4*(6), 063129.

Tiwari, S., & Tiwari, G. (2017). Energy and exergy analysis of a mixed-mode greenhouse-type solar dryer, integrated with partially covered N-PVT air collector. *Energy*, *128*, 183–195.

Torres-Reyes, E., Cervantes-de Gortari, J., Ibarra-Salazar, B., & Picon-Nunez, M. (2001). A design method of flat-plate solar collectors based on minimum entropy generation. *Exergy, an International Journal*, *1*(1), 46–52.

Verma, R., & Gupta, A. (2004). Effect of pre-treatments on quality of solar-dried amla. *Journal of Food Engineering*, *65*(3), 397–402.

Zogzas, N. P., Maroulis, Z. B., & Marinos-Kouris, D. (1996). Moisture diffusivity data compilation in foodstuffs. *Drying technology*, *14*(10), 2225–2253.

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Sustainable livelihood by HR capacity building in multicropping practices of Indian Eastern Himalayan region: A case study

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Sustainable livelihood by HR capacity building in multicropping practices of Indian Eastern Himalayan region : A case study

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Abstract

The indigenous people of Indian Eastern Himalayan region has been engaged in traditional farming practices for many years for their livelihood. The definition of livelihood has been redefined by the need new generation. Hence, they have started adopting cultivation of cash crop like large cardamom (Amomum subulatum Roxb), kiwi, sandal wood, large cardamom due to its lucrative revenue option. However, adopting standalone cultivation of large cardamom becomes matter of risky. Scientific multi-cropping along with large cardamom cultivation has become widely recommended for this locality. This paper attempts to highlight intervention of HR capacity building in multi-cropping along with large cardamom for sustainable livelihood in the said region.

Subject Classification: *Primary 91-XX, Secondary 91B44*

Keywords: *Large Cardamom, Human Resource Capacity Building, Multi-cropping, Sustainable Livelihood*

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1. Introduction

The Indian Himalayan region uniqueness of varied options of livelihood in comparison to the rest part of country. The major source of livelihood is farming of different crops, vegetables, and livestock with a major purpose for self-consumption only. The new dimension of livelihood such as expenses in education, health, communication has redefined the farming pattern [1]. As a result of which they have shifted towards multi-cropping, emphasizing revenue generating plantation. In the Indian eastern Himalayan region, the people of Lower Subansiri is distinguishably considered to be equipped with indigenous techniques of water harvesting, and collaborative farming. The paddy-Pisciculture has grabbed the attention of many modern days' agriculture scientist [2]. The majority people of region have shifted towards cash crop and as well as food processing, handicraft, animal farming. The horticulture based plantation has often been challenging due to its bulky dimension, and preservation. Cultivation of cash crop like large cardamom (Amomum subulatumRoxb), horticulture based cultivation has been main source of income for them. However, standalone cultivation of large cardamom is not sufficient to give them sustainability as a result multi-cropping concept is emerging among them. These days the cultivation of large cardamom is affected by phenology (flowering behaviour) due to heat, short life span, partial shade, viral diseases, pollination, extinction of original seed [1]. The multi-cropping practice along with capacity building with the large cardamom has been considered to be the focal point for the livelihood of the people [3]. It needs community based scientific optimal resource allocation from the point of long run sustainability. Community farming in this locality has been practised by the farmers in their indigenous manner [2]. However, modern day community farming aims at increasing different dimensions of the farming [4]. The country-wide community based farming can be beneficial for the modern technological capacity building [5]. The capacity building for manpower development through intervention of different outsourced agencies has also been observed in recent research work in both developing and underdeveloped economy [6], [7]. Further, the traditional farming techniques has also been redefined by the intervention of capacity building and value chain mapping [8], [9]. The paper discusses the need of HR capacity intervention through a case study with objectives: i) to analyze various and best combinations of multi-cropping along with large cardamom cultivation in the region

for sustainable livelihood among the cultivators, as well as ii) streaming human resource intervention for capacity building for the same.

The paper has been discussed in four sections, namely 1. Introduction 2. Research Approach 3. Cases Study 4. Conclusion. Introduction of the paper elaborates the current status and need of sustainable livelihood with the intervention of HR capacity building. Research approach of the case study comprises of methodology, study area and sampling. The section case study has been elaborated by i) Present status of livelihood practices in Himalayan region ii) Livelihood of marginal farmers in present context iii) Significance of skilled knowledge for large cardamom cultivation, and iv) Proposed framework of sustainable livelihood of marginal farmers. Lastly, conclusion summarizes the paper along with the scope of future study.

2. Research Process

2.1 *Methodology*

The research work is qualitative in nature comprising primary and secondary data. Primary data were collected through structured questionnaire vide personal interviews and personal observation for data validation. Whereas secondary data were collected from different sources of annual reports of government of India: ministry of small and medium enterprises (MSME), Census India, 2011, North Eastern Council Secretariat, Mission for Integrated Development of Horticulture, Government of India, business news, books, Spice board journal, Ministry of Rural Development etc. For this study here the combination of judgement and convenient sampling were used. The sample size for this study was 43 which represent almost 68% of total registered Large cardamom cultivators in Lower Subansiri.

2.2 *Study area and sampling*

From the sample it was found that 23% respondents belong from Ziro-I and other 77% sample belong from Ziro-II (Yachuli). In Yachuli it was given more emphasis because Yachuli is more famous and aggressive with Large cardamom cultivation than Ziro-I as Ziro-I is more famous for Kiwi cultivation. The sample also indicates that majority of the registered farmers belonging early thirty age bracket of male and very young generation is still not engaging with this emerging activity. Few females are registered as cultivators of large cardamom which can be considered as

sign of women empowerment. Even in the field of cultivation also mostly men are seen in engaging in the cultivation. The sample is associated with this cultivation from last 3 to 9 years which is very peak period for them.

3. Case study

3.1 *Present status of Livelihood practices in Himalayan Region*

Their major source of livelihood of Lower Subansiri includes vegetable cultivation where they mainly focus on Maize (Corn), Pumpkin, Chinese Cabbage, Potato, Ginger, Rice cum Pisciculture etc in large scale along with small kitchen garden. All the respondents have mentioned that since corn is one of the staple foods for them so all the cultivators go for this particular cultivation only to fulfil the need of his family. From the personal observation and interview it has been observed that all the cultivators go for maize and rice cum pisciculture cultivation dominantly. Regarding the labour for cultivation, in both areas the family members as well as hired labours equally contribute in doing this particular cultivation. In the locality of Yachuli, a new concept is emerging i.e. formalized cooperative concept among the neighboring farmers of this particular cultivation which is not practiced in Ziro-I till date...

3.2 *Livelihood of marginal farmers in present context*

The existing practice followed by the marginal farmers for their livelihood where the traditional way of practices is maintained to do large cardamom cultivation along with multi-cropping farming.

Fig.1 elaborates marginal farmers go for cash crop especially large cardamom cultivation to bear additional expenditure and other multi-

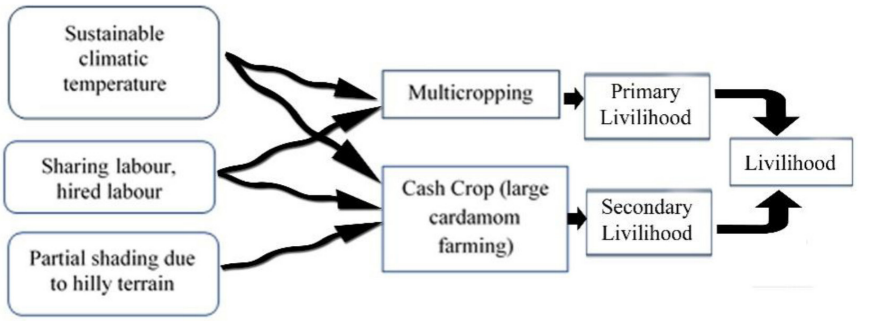

Figure 1

Conceptual Framework for livelihood of marginal framers

cropping is done for self-consumption. For multi-cropping they get suitable climatic condition with the help of sharing and hired labour but for large cardamom cultivation along all these, partial shading is very much required. At the same time, it can be said that though this cultivation had got the momentum in Arunachal Pradesh in long years back but its commercialization and in large scale just started two decades back. Income through large cardamom mostly fulfils the two priorities requirement, namely education, and medical expenses. Interestingly they are not accustomed with saving and investment in financial institutions. However, they are found to allocate careful financial saving portfolio for the farming activities. The entire sample of marginal farmers were agreed on this point that with large cardamom cultivation the sustainability is possible. But it again depends on area of cultivation, productivity etc. Multi-cropping of different vegetables and pulses along with large cardamom for their sustainable livelihood has been significantly observed in many parts of the said locality.

3.3 *Significance of skilled knowledge for large cardamom cultivation*

The cultivators had accumulated information about large cardamom cultivation from their friends and relatives which is purely personal pocket of sources. Government rarely conducts awareness programmes on this pattern of cultivation. There is a need to conduct awareness programme regarding scientific cultivation of large cardamom along with multi-cropping for the inclusion of more educated youth. Though, government organize different training sessions for large cardamom cultivators in minimum scale, not all the cultivators can avail this training session. Only the beneficiaries can avail these training sessions. According to the cultivators whatever knowledge and skill they have in this regard they are getting it through observation. Hence it is essential to point out here that government intervention in giving and creating capacity on various areas of cultivators is highly essential, so that the demotivating scenario as well as the failure cases can be converted in to motivating and successful case. Farmer of large cardamom need to possess knowledge regarding soil and climate as per the views of sampled respondents. In addition to this local forestry knowledge and disease protection knowledge are also vital for the cultivators. It was also observed that entrepreneurial skill, knowledge on market scenario, and plantation techniques are utmost essential to make this particular cultivation a successful one.

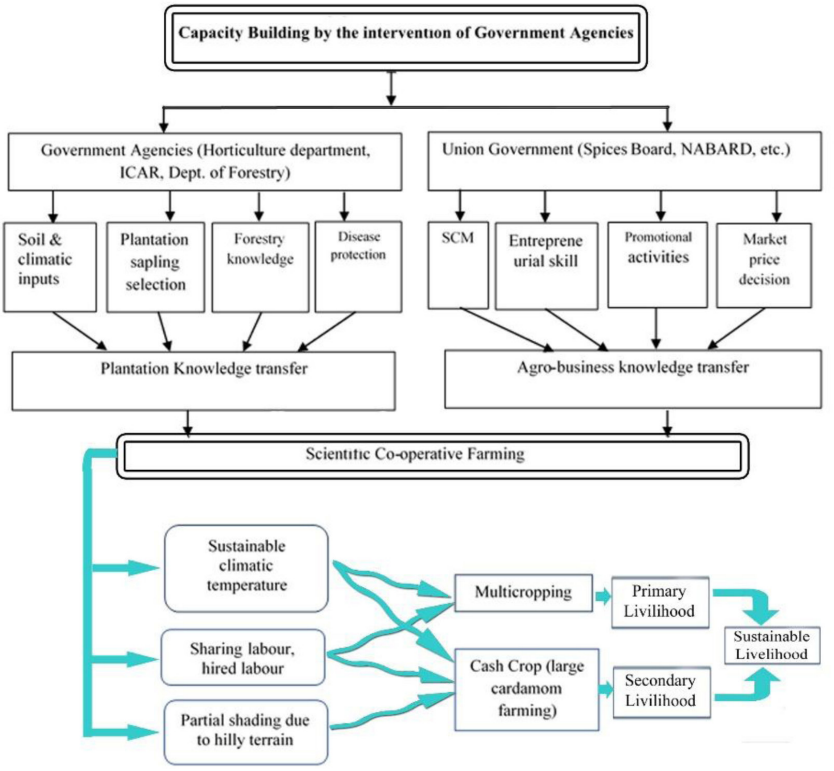

Fig. 2

Proposed Framework for Sustainable Livelihood of Marginal Farmers

3.4 *Proposed framework of sustainable livelihood of marginal farmers*

It was observed that these days the cultivators face lots of challenges in different stages of cultivation. All the challenges can be broadly divided in three categories, namely: i. challenges with plant are like diseases of virus and fungus. ii. issues related to market like price fluctuation and bargaining of middle man, and most importantly iii) lacking of trained human resources. The paper, in order to address the stated issues, has proposed a framework (Fig. 2) for the intervention of HR capacity building by different government agencies.

Proposed model emphasized on the knowledge transfer for both plantation and agribusiness work. The plantation knowledge includes i) soil, climatic condition, ii) selection of plantation sapling, iii) forestry knowledge, and iv) disease protection. This would build up confidence in

portfolio management of plantation through site selection and cropping layout for appropriate farming. Similarly, the indigenous farmers lack the knowledge of agro-business knowledge, through HR capacity building it can train farmers regarding i) supply chain management, ii) entrepreneurial skill, iii) promotional activities, and iv) market pricing policy. The synergy of plantation knowledge, and agribusiness knowledge would augment the scientific co-operative farming. The favorable climatic, sharing and hiring of farmers would promote both Multicropping most for their self-consumption fulfilling their primary livelihood need, and the cash-crop like large cardamom would fulfil the clothing, shelter, education, medical and surplus saving aims towards secondary livelihood need. The proposed framework will augment the trained manpower through transfer knowledge on plantation and agro-business. It will help marginal farmers in scientific co-operative farming.Many educational institutes have initiated to streamline the linkage between various government agencies to for knowledge transfer in this locality.

5. Conclusion

The research work highlights the significance HR capacity building for the indigenous farming community. The proposed knowledge transformation would augment the sustainable livelihood. The intervention of HR capacity building through the support of government in the said areas can ensure sustainable livelihood through large cardamom cultivation along with multi-cropping practices by the marginal farmers. On successful implementation of the proposed framework in the said region, it can act as role model for similar climatic and terrain condition.

References

[1] Pothula, A. I., Singh, A. I. "Postharvest Processing of Large Cardamom in the Eastern Himalaya: A review and Recommendations for Increasing the Sustainability of a Niche Crop". *Mountain Research and Development* (MRD), vol. 33, no. 4, November, 2013, pp. 453-462, https://doi.org/10.1659/MRD-JOURNAL-D-12-00069.1

[2] Choudhury S., Pant R.M. et. all. "Destination Branding of Ziro Through Potentiality of Bio-tourism". *Bioprospecting of Indigenous Bio-resources of North-East India*, August, 2016, pp. 329-337, DOI: 10.1007/978-981-10-0620-3_21

[3] Ferreroa G., et. all. "Capacity building and training approaches for water safety plans: A comprehensive literature review". *International Journal of Hygiene and Environmental Health*, vol. 224, no. 4, February, 2019, pp. 615-627, doi: 10.1016/j.ijheh.2019.01.011.

[4] Tontisirin K., Nantel G., and Bhattacharjee L. (2001) "Country-wide community participation for nutrition improvement: Lessons learned from Thailand". *Ecology of Food and Nutrition*, vol. 40, no. 6, 31st August, 2010, pp. 685-697, DOI: 10.1080/03670244.2001.9991677.

[5] Kamruzzaman M., Takeya H. (2008) "Influence of Technology Responsiveness and Distance to Market on Capacity Building". *International Journal of Vegetable Science*, vol. 14, no. 3, 2018, pp. 216-231, DOI: 10.1080/19315260802164848.

[6] Johnson C. P., Williams P. L. et. all "The Capacity Building Experience of Women Engaged in Determining the Cost and Affordability of Healthy Food in Nova Scotia, Canada". *Journal of Hunger & Environmental Nutrition*, vol. 10, no. 3, 14th April, 2016, pp. 356-378. Journal Database, http://dx.doi.org/10.1080/19320248.2014.962769.

[7] Santosh Durugkar & Ramesh C. Poonia (2017) Optimum utilization of natural resources for home garden using wireless sensor networks, *Journal of Information and Optimization Sciences*, 38:6, 1077-1085

[8] Eva D., Artemis K. "Capacity Building in Agricultural Biotechnology in Turkey". *Food Reviews International*, vol. 19, no. 4, 2007, pp. 437-445, DOI: 10.1081/FRI-120025484.

[9] Vaibhav Bhatnagar & Ramesh C. Poonia (2018) Design of prototype model for irrigation based decision support system, *Journal of Information and Optimization Sciences*, 39:7, 1607-1612

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Sustainability of UAVs in developing countries: Prospects and challenges

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Sustainability of UAVs in developing countries : Prospects and challenges

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Abstract

Unmanned Aerial Vehicle (UAV) or generally well known as drones created opportunities in socio-economic development in developing countries. Augmenting these technologies through capturing accurate and real time data in a cost effective way created prospects and challenges of UAV. However, the types, policies that govern their flying altitudes and the technology will be required to regulateand monitor these flying machines, which do not carry human operators and fly autonomously in reference to the developing countries is discussed.

Subject Classification: *Primary 91-XX, Secondary 91B44*

Keywords: *Unmanned Aerial Vehicle (UAV), Developing countries, Re-mapping, Satellite and aerial imagery, Drone Regulations*

1. Introduction

UAVs have influenced various sectors of a country's economy. The successful implementation by the developed countries have been

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influencing developing countries. On the contrary, policy makers of developing countries are apprehensive of negative consequences of visual surveillance and dropping packages [1]. In developing countries drone are mostly used for recreation activities. However, recent development has seen whooping increase in the application of nation-states providing monitoring options across the international borders, and journalism [1]. The challenges now lie in the policy making of regulating the drone users and limiting the flying zones within the premises of a country's jurisdiction [2]. Developing nation like India is working on framing suitable policies to fly this trending culture of flying drones. The factors regarding privacy has been analyzed [3] and in this paper a broader perspective of the sustainability of the UAVs, considering the privacy prospects will be briefly covered in the context of eastern Himalayan region of India.

2. Literature review of need and importance of UAV or Drone

UAV have been one of the fascinating devices that human race have come to realize. From large quadcopters to pocket size designs, drones have come a long way. The sectors utilizing this technology includes: Agriculture, Forest and wildlife, Disaster management, Healthcare, Mining, Homeland Security, Urban development and construction, and Traffic management. In addition to the mentioned sectors, other sectors like the telecom, insurance, energy and utilities are also exploring the deployment of drones to help for real-time augmenting, and enhance in safety and cost effectiveness of their respective business chains.

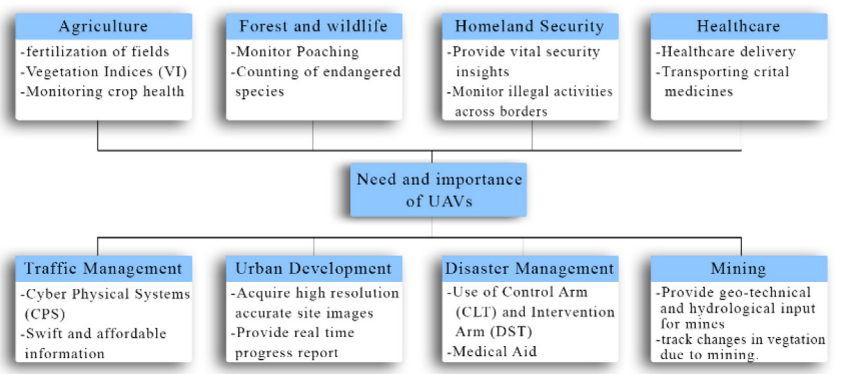

Figure 1

Need and importance of UAV

In Agriculture, drone imaging [4]creates soil map after ploughing helps in determining soil fertility. Similarly, vegetation indices (VI's), health of the crop can also be determined [5].In disaster management, drones have acted as crucial responsive system [6]. The role of drones is not limited to real-time surveillance, search and rescue missions but can also ensure delivery of essential medical first aid and food items to affected areas [7].Managing forest and wildlife is onerous considering the length, breadth and complexity of the landscape. Drones are equipped with high pixel cameras [8] helps in monitoring of illegal activities like poaching [9]. Important activities like tracking wildlife, even the most minute, and counting [10] of rare, endangered, specific species have become much easier. Concerning the health care industry, drones have played vital role in subduing epidemics by delivering [11] healthcare items [12] and transporting critical medicines [13] in the rural areas. Geospatial block chain, its promises, challenges, and scenarios in healthcare has also been discussed in [14],[15].Drones support numerous security applications and the real-time surveillance can provide vital security insights [3]. Besides, the sensor-equipped drones are able to detect illegal activities in the border areas [16]. Drones can increase effectiveness in the mining process. Drones are currently used to obtain data related to geo-technical as well as hydrological input for mines for open-pit types [17]. They also help in delivering tools in exploration and survey sites. Concerning the degradation of the environment due to mining, meaningful digital model report structuring helps to track changes in the vegetation because of extensive mining [18][19].

Due to boom in urbanization, traffic management has become a major challenge in the cities. Data acquired with the help of drones, which are also known as cyber-physical systems (CPS) [20] alleviates the identification of defects, patches on the highways, situation of traffic at different stages of the day, obstructions, detection of violation, raising of alerts emergency SOS and various unpredictable events that may arise. In urban planning and development, drones help in acquiring high-resolution accurate site images and capture them efficiently [21]. Through instant volumetric estimations as well as mapping progress at construction sites against set schedules project monitoring provides real time progress reports [22][23].

3. Evolution of Drones

Fig.1 summarizes rolling back to the first use of drones for military purpose during 1900s as well as civil deployment dating inline with 2000s,

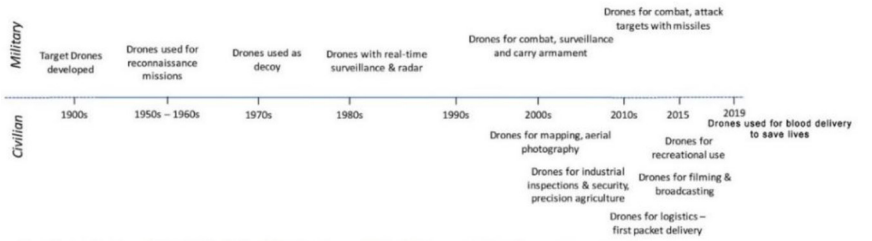

Figure 2

Time line of military and civilian uses of drones[25]

research and developments of UAVs enhancing their utility evolving at a fast rate over the last decade [24]. The technological developments in the key factors like the flight control, position control, sensors, aerial capacity and high-end improvement in the communication led to new specific industry for UAVs. In 1900s, the autonomy of drones was limited and were different from the drones we see these days. Mostly used to collect information during recon operations or missions involving high stakes, drones proved very handy. Keeping in mind the advantage it gave the military, there was no looking back in developing the drone technology further [25]. The functionality and capacity improved in course of time giving rise to a completely new level generation of drones that we see now. (see Figure-1).

Unlike military UAV providers, civilian UAV manufacturers aim to supply the maximum number of products in the market to commercialize them and lead the market in production and diversifying as much as possible.

3.1 *Types of drones*

Drones have drastically diversified after the commercialization of civilian application drones.Various missions demanded different kinds of UAVs, so it is beneficial to classify them according to their mission capabilities. They may be categorized as: [27] (see Figure-2) :HTOL (Horizontal take-off landing), Hybrid Model (tilt-wing, tilt-rotor, tilt-body, and ducted fan), VTOL (Vertical take-off landing), Heli-wing, Helicopter, and Unconventional varieties. This categorization differentiates the drones that may be applicable for military or civilian use so that policy formulation for permission of flight will be more at ease. Drones have evolved into a device that anyone can possess, so the policy makers

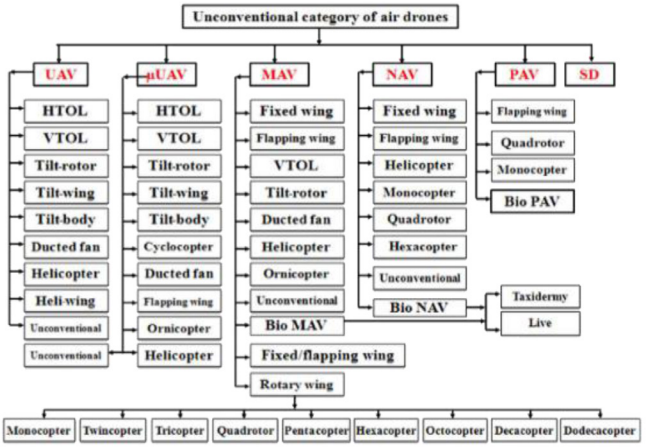

Figure 3

Different types of air drones[25]

Figure 4

Classification of Drones[26]

have to keep in mind the parameters that may cause harm to the general population as a whole.

In addition, according to the Drone Databook [26] drones are classified into three classes based on their weight: i) less than 150Kg (Class

Table 1

Drones in developed country at a glance [31]

United States of America (USA)			**France**	
	For Fun	**For work**	**For Fun**	**For work**
Weight	< 25 kg	< 25kg	> 800 gms	> 800 gms
Registration	FAA*	FAA*	Only for > 800 gms	Only for > 800 gms
VLOS	Mandatory	Mandatory	Mandatory	Mandatory
Restrictions	Limited to some space category	flown over people, Height > 122m, speed > 160 kmph	Overflight curbs, >150 m, night use permission	Overflight curbs, >150 m, night use permission
Pilot license	NA	Mandatory	Theoretical exam and undergo basic training	Training for drones weighing more than 800 gm
	United Kingdom (UK)	**Germany**	**Australia**	**Japan**
Weight	NA	> 5kg	NA	NA
Registration	CAA*	Mandatory > 5kg	Mandatory	Mandatory Government Approval
VLOS	Mandatory	Mandatory	Mandatory only daytime	Mandatory, only daytime
Restrictions	Cannot be flown > 122m, + curbs for camera drones	Overflight curbs, + curbs for camera drones	Height >120m and fly > 30m of habitat, Overflight curbs Drones >100 gm, 5.5 km away from aerodromes	Height ceiling of 150m and cannot be flown <30 m of people.
Pilot license	NA	Mandatory >2kg	Mandatory for commercial	NA

I) used for commercial and civilian usage, ii) between 150 to 600 kg (Class II) used for delivery system for some heavy duty work as the payload and, iii)above 600 kg. (Class III).

Drones are emerging as an effective option for being more cost effective in smaller projects than larger mapping projects handled by satellite and aerial imagery. These specific operations in dollars are in the region of $10,000 for deploying a helicopter while the same operations deploying a drone will costs $10,000 [28].

3.3 *Strength and weakness of Drones*

Strength of drones includes maintaining a safe environment, cost effective technology, easily controllable, quality imaging and life streaming. Similarly the weaknesses are intrusion into privacy, endangers public safety, unclear rigid legislation and potential threat to nature.

4. Drones in Developed Countries

It can be observed that the developed countries have some regulations in common. Especially the Visual line-of-sight (VLOS) [29], which is a technical term for Visual Line of Sight of the drone Pilot with respect to the drone that is being piloted. The line of sight is 500 meters from the pilot and is one of the most vital regulations to keep the pilot responsible. In the country like the USA [30] and France there are institutions where aspiring pilots can train and obtain license which is a very remarkable initiative as it will produce responsible drone pilots.

5. Drones in Developing Countries

Developing countries are not far behind considering the countries like India and China. China although categorized as a developing country is one of the leading manufacturer of drones, with their country based drone company DJI headquartered in Shenzhen, Guangdong which has manufacturing factories throughout the globe. In the context of India, DRDO located in Bangalore are the main developers of drones, but are mainly concerned with the military application. The countries like Brazil, Colombia, Costa Rica, Indonesia, Mexico, Nigeria, Pakistan, Philippines, Thailand, Tunisia and Vietnam are some that are worth mentioning. It is astonishing to know that besides military applications, China tops the drone industry with the civilian sector alone over 15,000 UAVs operating as of the end of 2013 [32]. However, the flying regulations may not be

Table 2
Drones in developing country at a glance [31]

	China	India
Weight	7-116kg	Micro, Mini, small and Large weight categories
Registration	NA	Mandatory at Digital Sky Portal and bear Unique Identification Number (UIN)
VLOS	Mandatory	Mandatory
Restrictions	Cannot be flown > 120 m	Nano drones (250g) flown <=15m, other drones <=122m
Pilot license	Mandatory>116kg, commercial	Mandatory >2kg
Fly Zones	Defined	Defined (green, red and yellow)

at par with the developed countries. Following are China's and India's flying regulations.

The regulations of these two countries is being considered as they are as one of the most populated and adapting to drone solution will increase the use of drones opening up many avenues for the upcoming generation. As for the mentioned countries, their areas for operation are comparatively smaller although they are building up their UAV technology.As developing countries frame their policies, the regulations need to be at par with the possible misuse of drone technology since there are several factors that needs to be addressed about drones and their applications [33].

6. Case: Prospects and ChallengesinEastern Himalayan Region

The land locked Eastern Himalayan Region (latitude 27.59°N, longitude 93.35°E) is one of the most affected areas during disasters. This region is located in one of the high rainfall zones and the region stretches from snow covered and inhospitable mountains to flood plain areas. The population is marginally exceeding over 13 lacs and citizens are residing in the diverse area of over 80,000 km square. The population density of this land locked Eastern Himalayan region sparse, that is not more than 20 citizens per kilometer square of area [34] and is also a multi-hazard

prone region, and is highly susceptible to various types of natural and manmade disasters.Therefore, the prospects of UAVs in the said region located in developing countries can be 1) Creation of job opportunities, 2) Enhancement of vital activities like Urban Development, Agriculture, Disaster Management, Traffic Management, Healthcare, Forests, Security, Wildlife and Mining, 3) Training institutions for drone pilots, and 4) Re-Mapping of historical civilizations. The major threat ofeconomic growth is to assure wide scaleagreement of regulations, with appropriate equivalent level of safety (ELOS). The advancement in technology would create a competitive atmosphere, and uneven competition could be challenging. Unfamiliar audience, businesses unaware of or deliberatelyignoring the regulations being formulated by Government agencies, customized need based training and other activities insurance will also be equally challenging.

7. Conclusions

The sustainability of UAVs or drones in developing countries is promising. The policies for piloting the drones need to be proper, keeping in mind all the factors that may be a potential threat to the act of deploying drones for any other purposes. Scope for drones is quite high in developing countries as the market is niche and the trained drone pilots can create employment in many industrials sectors. The most notable field is the aerial cinematography where drones are mostly deployed, and for an entrepreneur one can vision a phase where solopreneurs group themselves up with the rest of the professionals with specific knowledge to operate in a multi-disciplinary profession like a licensed soil and land surveyor providing professional services to various industrial and research operations.Developing countries seem to require drone technology more than the developed countries as the developing countries are highly populated and it is impossible to reach out to all the citizens especially the health-deprived sections of the society living in the worst condition. In rural areas, the drones will play the role an autonomous bird to drop the first aid, and medical necessities urgently needed. In rescue and search operations, drones will help the rescue and search team to locate the victim providing them the bird's eye view as the developing countries have many inhabited areas where people have no access to roads generally covered with thick flora and diverse fauna. These avenues will surely throttle developing nations to attain the so adjudged developed stage.

References

[1] R. Clarke, "Understanding the drone epidemic," *Computer Law and Security Review*, vol. 30, no. 3, pp. 230–246, 2014.

[2] C. Stokel-Walker, "Why drones cause airport chaos," *New Scientist*, vol. 241, no. 3213, p. 10, 2019.

[3] R. L. Finn and D. Wright, "Unmanned aircraft systems: Surveillance, ethics and privacy in civil applications," *Computer Law and Security Review*, 2012.

[4] E. R. Hunt and C. S. T. Daughtry, "What good are unmanned aircraft systems for agricultural remote sensing and precision agriculture?," *International Journal of Remote Sensing*, vol. 39, no. 15–16, pp. 5345–5376, 2018.

[5] I. B. Yonah, S. K. Mourice, S. D. Tumbo, B. P. Mbilinyi, and J. Dempewolf, "Unmanned aerial vehicle-based remote sensing in monitoring smallholder, heterogeneous crop fields in Tanzania," *International Journal of Remote Sensing*, vol. 39, no. 15–16, pp. 5453–5471, 2018.

[6] Y. Karaca *et al.*, "The potential use of unmanned aircraft systems (drones) in mountain search and rescue operations," *American Journal of Emergency Medicine*, vol. 36, no. 4, pp. 583–588, 2018.

[7] A. Claesson *et al.*, "Drones may be used to save lives in out of hospital cardiac arrest due to drowning," *Resuscitation*, vol. 114, pp. 152–156, 2017.

[8] J. Witczuk, S. Pagacz, A. Zmarz, and M. Cypel, "Exploring the feasibility of unmanned aerial vehicles and thermal imaging for ungulate surveys in forests - preliminary results," *International Journal of Remote Sensing*, vol. 39, no. 15–16, pp. 5504–5521, 2018.

[9] Agence France Presse, "Kenyan reserve to fly drones to tackle rhino poachers," *Agence France Presse Newswire*, 2012.

[10] J. Linchant *et al.*, "UAS imagery reveals new survey opportunities for counting hippos," *PloS one*, 2018.

[11] K. D. Atherton, "Researchers Successfully Transport Blood By Drone," *Popular Science*, 2015.

[12] B. McCall, "Sub-Saharan Africa leads the way in medical drones," *The Lancet*, 2019.

[13] K. Bhatt, A. Pourmand, and N. Sikka, "Targeted Applications of Unmanned Aerial Vehicles (Drones) in Telemedicine," *Telemedicine and e-Health*. 2018.

[14] M. N. Kamel Boulos, J. T. Wilson, and K. A. Clauson, "Geospatial blockchain: Promises, challenges, and scenarios in health and healthcare," *International Journal of Health Geographics*. 2018.

[15] M. Church, "We need drones, robots, and autonomous ambulances," *BMJ (Online)*. 2015.

[16] M. B. Salter and C. E. Mutlu, "Psychoanalytic theory and border security," *European Journal of Social Theory*, 2012.

[17] S. Annavarapu and G. P. Kumar, "Development of drones to collect geotechnical data in large underground mines," in *Application of Computers and Operations Research in the Mineral Industry - Proceedings of the 37th International Symposium, APCOM 2015*, 2015.

[18] S. de Roos, D. Turner, A. Lucieer, and D. M. J. S. Bowman, "Using Digital Surface Models from UAS Imagery of Fire Damaged Sphagnum Peatlands for Monitoring and Hydrological Restoration," *Drones*, 2018.

[19] Gupta, Yash, and Manoj Sharma. "Estimating sustainable location for harvesting solar power using geographical information systems and remote sensing methods." *Journal of Information and Optimization Sciences* 41.1 (2020): 51-60.

[20] M. Vierhauser, J. Cleland-Huang, S. Bayley, T. Krismayer, R. Rabiser, and P. Grünbacher, "Monitoring CPS at runtime - A case study in the UAV domain," in *Proceedings - 44th Euromicro Conference on Software Engineering and Advanced Applications, SEAA 2018*, 2018.

[21] N. Mohd Noor, A. Abdullah, and M. Hashim, "Remote sensing UAV / drones and its applications for urban areas: A review," in *IOP Conference Series: Earth and Environmental Science*, 2018.

[22] C. Snow, "The Truth About Drones in Construction and Infrastructure Inspection," *Skylogic Research, LLC*, 2016.

[23] Y. Li and C. Liu, "Applications of multirotor drone technologies in construction management," *International Journal of Construction Management*, 2019.

[24] F. Giones and A. Brem, "From toys to tools: The co-evolution of technological and entrepreneurial developments in the drone industry," *Business Horizons*, vol. 60, no. 6, pp. 875–884, 2017.

[25] A. Sehrawat, T. A. Choudhury, and G. Raj, "Surveillance drone for disaster management and military security," in *Proceeding - IEEE International Conference on Computing, Communication and Automation, ICCCA 2017*, 2017.

[26] D. Gettinger, *The Drone Data Book*. Annandale-on-Hudson, New York; Washington, D.C., 2019.

[27] M. Hassanalian and A. Abdelkefi, "Classifications, applications, and design challenges of drones: A review," *Progress in Aerospace Sciences*, vol. 91, no. November 2016, pp. 99–131, 2017.

[28] "Price wars: counting the cost of drones, planes and satellites," no. http://droneapps.co/wp-content/uploads/2015/08/composite.jpg.

[29] "HighEye.com." [Online]. Available: https://www.higheye.com/faq/.

[30] "The Center for the Study of the Drone at Bard College." [Online]. Available: https://dronecenter.bard.edu/.

[31] T. E. Times.indiatimes, "Drone delivery: A look at the current regulations across globe," 2019. [Online]. Available: https://economictimes.indiatimes.com/tech/hardware/drone-delivery-a-look-at-the-current-regulations-across-globe/articleshow/71514277.cms.

[32] "Lists of UAVs in China." [Online]. Available: https://en.wikipedia.org/wiki/List_of_unmanned_aerial_vehicles_of_China.

[33] S. Sim, H. Kwon, and H. Jung, "A Study on Utilization of Drone for Public Sector by Analysis of Drone Industry," *Journal of the Korea society of IT services*, 2016.

[34] "Arunachal Pradesh Population 2011-2019 Census," 2011. [Online]. Available: https://www.census2011.co.in/census/state/arunachal+pradesh.html.

Augmenting Farmer Producer Company through Aligning Indigenous Community Based Beliefs and Practices: Learnings from Abotani Community of Eastern Himalayan Region

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Abstract:

Abotani community of eastern Himalayan region have been recognized as one the ethnic groups with comprising of many tribes of same antecedent. Their old scientific management of natural resources through their indigenous belief and practice system. The traditional knowledge of the community, though has not been recorded in the writing format, has been preserved by passing the knowledge from one generation to another generation by word of mouth and daily need-based practices. The paper highlights the inter-relationship between indigenous community-based beliefs and practicing cooperation and management of natural resources and farming practices for many centuries. preserve and scientific agroforestry approaches such as The Abotani community has also been involved in community management practices like Kebang, Kabo,Soru-Ruth, Rongo-Ray, Aka Mele, Buling. The paper has emphasized the similarity with that of present days' village community management system and modern. Finally, the paper has attempted to focus on the success story of a commercially viable cooperative farming.

Keywords: Abotani, Farmer producer company, Subansiri farmer Producer Company

1. Introduction

The eastern Himalayan region is enriched with its natural resources and favorable climate for different vegetation. The region has diverged topography where the farming has been integral parts of Abotani community that possesses a rich history of practicing indigenous community-based agroforestry concept for the last many centuries. The Abotani community residing in the eastern Himalayan region comprises of many different tribes, which belief to be antecedent of Abotani. These tribes are Galo, Tagin, Adi, Nyishi and Apatani. The history of these community has displayed the idiosyncratic farming practices where a large area of forest land is cultivated under few individuals (Elwin, 2012). As an idiosyncratic farmer, they face many challenges in the accumulation of funds for commercialization of the agri-products. To overcome these all constraints and challenges they have their own indigenous community-based beliefs and practices. For instance, Rongho-Rey of Nyishi tribe (group farming), Rongho-Rey (temporary gathering of villagers for farming) and Soru-Ruth (group hunting), etc. shown the ancient intact of such cooperation by the community (Elwin, 2014). With exposure to the outer world and acquaintance to Market Avenue now farmers are appealing towards commercialization of their surplus products for more viable incessant income for livelihood. In the early 2000s, the introduction of Farmers Producing Companies (FPC) has shown a ray of reliefs for all individual farmers in the overall context. FPC is a first of its kind with hybrid or modified version of cooperative societies. However, the formal procedures to establish the FPC often creates challenges for the ethnic community. As a result of which, during the formative stage of production of FPC, the acceptance was very low. Subansiri Farmer Producer Company (SFPC) has been initiated and managed by the Abotani community that has acted as a role model for the commercialization of farming in the said locality. It has streamlined collective bargaining power, market accessibility, infrastructure development, exposure to on-farm and off-farm training. The objective of the paper includes i) ethnic practices of agroforestry through community participation, ii) level of acceptance of FPC by the ethnic group and their benefit. The present research work is qualitative in nature. The secondary data for research work has been carried out with the review of published papers in journals and books of the related area. Similarly, the primary data sources were interview with personnel of SFPC, financial institutions, state rural development, department of horticulture, and members of informal communities such as Kebang, Kabo, Soru-Ruth, Rongo-Rey, Aka Mele, Buling. Nyoub (village priests), and marginal farmers of Abotani community were also interviewed. The data were also validated through observation study. The paper includes five parts and has followed a sequence to address various objectives. Different subsections are 1. Introduction, 2. Brief about the Abotani community, 3. Challenges and prospects of FPC for Abotani community, 4. Status of FPC managed by Abotani, and 5. Conclusion.

1.1. Brief about Abotani community

Abotani is believed as the person who as of late showed the path to salvation and prosperity life ahead with the wisdom and knowledge of indigenous methods of rice cultivation, Farming and rearing of animals, etc. headway (Riba, Tomo,2013). The Land of Abotani or Abutani community is

considered as the largest ethnic groups among the whole population of the Eastern Himalayan region (Hilaly S, 2018). The embracing of Nyishi, Adi, Galos, Tagin and. Apatani. Abotani, is viewed as the base ancestor of the Abotani (clans) party of individuals in the Himalayan region. (Abo or Abu: father, Tani: human) for example, Nyishi, Apatani, Adi, Galos and Tagin all these ethnic groups shared the beliefs of precedence from one antecedent called as Abotani. 'All in oneness's is what core beliefs system that builds cohesiveness among these different tribes for centuries (Ramya T, 2012). Donyi-Polo (Sun-Moon) religion by the Abotani reflects the influence of nature (Murtem, Chaudhry, 2014). The Abotani community dwells in the hilly terrain of the eastern Himalayan region of India is located between 26.28° N and 29.30° N latitude and 91.20° E and 97.30° E longitude and has an area of 83,743 km2 (32,333 sq. mi). All these sub-tribes may belong to

the same antecedent, but their dialogue, attire, marriage rituals, ceremonial, festivals vary in many ways.

Fig. 1 - Agroforestry practices by Abotani Community.

There is the uniqueness of diversity in oneness flamboyantly exhibited by these tribal ethnic groups. Each tribe celebrates their major festivals with full traditional gaiety to express their tenderness, sympathy and mutual respect towards nature and its ecosystem. For example, the Nyokum festival is celebrated every year by Nyishi tribe in the months of March to mark the beginning of the monsoon or harvesting period. Especially this festival is organized and celebrated to ask for greater productivity and prosperity of the whole community with the grace of Syi-Doni (Mother Nature). Among ethnic groups, there is an old traditional way to keep records of the family's genealogy.

For the last many centuries such old traditional and effective records keeping of such generation information which is coded with its own sole individual identities. Each of these ethnic groups has been engaged with different dialogues and accent which again exhibited its unique blend of tribal people of the Himalayan region (Adhikari, 2007).

1.2. Indigenous community-based practice system of Abotani community

Despite region specific hurdles, Abotani community groups had overcome challenges for its endeavour toward prosperity and wellbeing of whole communities (Elwin, 2012). The concept of cooperative may sound sporadic and new to these people, but for many centuries community based drove had led these people to overcome any obstacles for many generations. Perchance it is about indigenous methods such as RonghoRey(group farming) of Nyishi tribe, *etc* explicitly exhibited the cohesive and cooperative nature among these communities to comes together for common causes. In Adi tribes, Kebangs is community-based village councils formed by the elders (Elwin, 2014). The elder's villagers are its members and acquired through its merits and expertise in different fields. An advanced level of administration and crystal clear of the hierarchy of authority and responsibilities unveiled early administration and cooperation among these ethnic groups. Such councils have existed from immortal days. Prolongation of community-based practices of Galo tribe also showed the essence of cooperative in their community based-councils board called Kabo (village council) led by elders of villagers in Dere (community hall) and inclusively run by Gaon-Burahs etc. All-inclusive we need to fill this gap between two crucial factors one indigenous community-based beliefs and practices of cooperation into cooperative farming for augmentation of incomes among them (Singh et al.2010).

1.3. Abotani and Agroforestry system

The eastern Himalayan region is gifted with rich resources in both terms of fertile soil compositions and variation favorable climate from high temperate to typical tropical falling with altitude ranges 0 to 5,000 meters high and above favorable for agroforestry system among the Abotani community (Fig.1). The community has efficaciously adopted the evolving social, economic and environmental changes for their coexisting with the ecosystem with the help of indigenous techniques and practices ((Selvan et al.2017, Chandra et al.2011, Choudhury, 2016). For instance, multilayers farming with teak and orange plants along with agricultural crops like black cardamom, ginger, Cinnamon, turmeric etc are being practised by the Nyishi tribe (Fig.2). Toko-Patta (Livistona JenKinsiana Griff) from Adi community presented important of this tree in the conservation of endangered tree species in the eastern Himalayan region by the Adi tribe (Singh et al.2010).

Similarly, Apatani tribe has also been practising a unique bamboo along with pine homestead agroforestry system (Tangjang & Nair, 2016) Alder based farming has also been widely popular among these community to replenish the lost fertility of the soil with perennial crops (Sharma et al.1994). This Abotani community is also known for its traditional medicines reservoir from early human civilizations. Amid community, they have a rich and abundant inheritance of folk medicines and its uses to treat many common ailments for centuries (Ramaya T.,2012)

There are different folk medicines uses and beliefs are profound by these groups in the preservation of rare medicinal plants and herbs by protecting and concealing the large area of forest called Uie-Norho

(spirits of the forest) large forest area under community councils for protecting the agroforestry system even today (Sarkar et al.2015, Chakrabarty and Bhattacharjee, 2006).

Some of the medicinal plants with their usage practice is shown in Table-1:

Table 1 –Medicinal Plant usage practices by Abotani

Botanical Name of Medicinal Plants grown in the Abotani belt	Traditional Usages and practices by the Abotani
Abroma augusta	Appetite, dysentery
Coptis teeta Wall.	eye diseases, appetizers, anti-inflammatory and skin disorders
Embelia ribes Burm.f.	Astringent, anthelmintic, tonic,
Holarrhena Antidysenterica	Piles, dyspepsia and dysentery and skin disorder.

But on the contrary, this intact concept of community cohesive never been put on the right track toward cooperative farming practices for commercialization of farm produces production at any level. The idiosyncratic farm management system has its own difficulties. For instance, lack of financial aids for both on-farm and off-farm inputs, road connectivity, logistic, warehouse, cold-storage facilities for perishable farm production, and very less exposure to market linkages. Today with steady development of infrastructure and economic upliftment the major population has felt the importance of the agriculture activities as a not only for self-consumption in addition to it, the commercialization of surplus production markets for augmentation of income for livelihood. The problems associated with idiosyncratic approach can be mitigated through the formation of FPC (Bhattacharjee, 2010). The FPC or pooling of people and resources for the common interest will help the individual to come together and aggregate the production at large quantity which will further help the farmers to supply the product at large quantity with more bargaining power towards buyers (Bikkina et al, 2017).

Fig 2. Multilayer farming practice by *Abotani* community.

The conventional/traditional practices of farming and producing and solely managing the entire process from sowing to selling the surplus product into the market are involved with higher production costs, in addition to that, low profits with lesser freedom to bargaining power as individual farmers. This paper generally highlighting the benefits of working as groups in the arena of farming in the interest of commercializing of farming activities in a broader perspective for more viable, sound livelihood option for a living (Wanyama,2014).

1.4. Proposed model: challenges and prospects of FPC for Abotani community

It has been observed that this centuries-old indigenous practice has added a more competitive edge by focusing on FPC which help many emerging FPC into the success story of this model introduced by the government. On evaluation, this new modern concept of group farming with old beliefs and practices of community-based work pattern there is a similarity of team-work and the formation of groups and essence of a team led by leaders is somewhat shown the cohesive quality work by these community. For instance, many FPC has excelled and reaped the benefits by joining as a member company with accessibility to micro/macro credits, loans, storage, drying facilities, and most important market linkage with more exercising of bargain power.

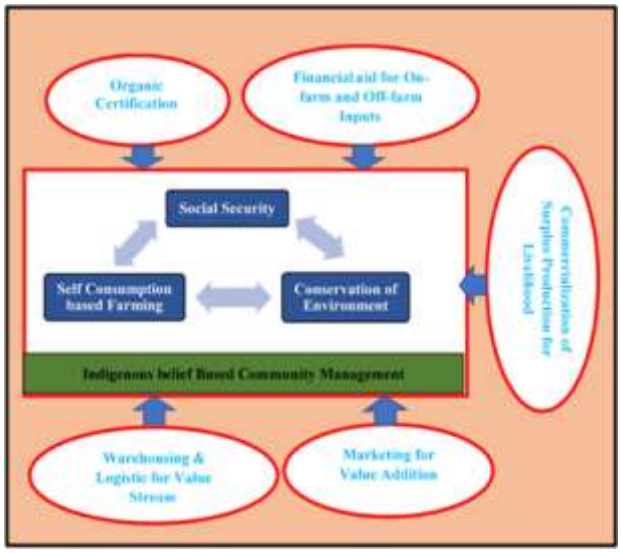

Fig 3. Proposed model of FPC with ingenious belief system.

The major's challenges face by farmers create an environment of professionalism approach, as the FPC is formed by more than 100 members with the same common interest and large numbers of the members, farmers from no formal education unknown to the management proficiencies and practices. The companies headed by farmers generally failed to cope up with the dynamic business world. Even the hiring of professional from

cities the management linkage totally failed in many cases. (Bikkina et al, 2014), Wiggins et al.,2010). The other major issue is approval of credits aids by concern institutes vice versa. Even with so many Recompenses, the full pledge implementation and integration of both indigenous and modern concept of cooperative farming is a matter of observation and need research for further conclusion in the coming years. the few constraints that have merely unable to justify the true meaning of cooperative in real sense is due to the extensive intercession of the government side (Trebbin, 2013).

Fig.3 elaborates the concept of modern days FPC concept that can be blended to streamline the indigenous time immemorial community system of Abotani community. The indigenous system are interdependent on three components: social security, conservation of environment, and self-consumption based farming. These three components can be further sharpened through the inclusion of components of FPC like organic certification, financial aid for farm inputs, warehousing, logistic, marketing, and commercialization of surplus production for livelihood.

1.5. Status of FPC managed by the Abotani Community

The FPCs are known as the hybrid or improvised version of co-operative. It is more significant with the features of private enterprise. There is an extensive participant of the farmer in overall activities of the organization in areas like decision-making, selection of board members and business-related decisions (Bikkina et al, 2017), Mondal,2010). Few FPCs run by indigenous farmers groups are successful.

1.6. Study Organization: Subansiri Farmer Producers Company

Subansiri Farmer Producers Company (SFPC), is a group of 281 individual farmers with total land covered more than 500 ha. The mission and objectives of SFPC are to increase farmers' incomes, to increase production and the most significant role is to empower each individual as well the whole community. SFPC has also given more emphasis in more professional touch to its administration by hiring professional personnel from outsourcing. The SFPC farmers are from Abotani community mainly from Nyishi and Apatani tribes. The SFPC was formed in year, 2016 with the collaboration and guided under the state hired a private partner 'Oppu Engineering & Agro service'. The two majors crops cultivated under the company is Kiwi and large cardamom with multiple crops farming methods with fruitful result. For instance, the qualitative raw material supplied has helped in establishing international popular kiwi wine Nara-Aba. The model of SFPC has shown greater outcomes in terms of augmentation of income by aggregating and selling a larger amount of product within the time frames of demands. Besides, kiwi wine manufacturer, also reaping the benefits of procuring a large quantity of raw product within its locality with cheaper prices. It's a win-win situation for both producers and manufacturer. On contrary, half of these SFPC is engaged in the cultivation of large cardamom and with the concept of FPC witness improvement in bargaining power and product quality management and greater exposure to information related to market linkage and more benefits in common is access to funding agents (Bikkina et al, 2017, Shelar, 2012, Mondal, 2010).

1.7. Conclusion

The present studies suggest that both indigenous and modern concepts can act as complementary to each other and with their unique quality is viable for augmentation of locally produced product and income, bargaining power of individual farmers. The integration of both concepts can lead to the more sustainable management of resources in a very effective manner. In the long run, these sorts of practices can help in forming a successful business ecosystem for Abotani community. The study infers the importance of indigenous community based knowledge for improvising relation among different tribes. Besides, it can protect and preserve old beliefs and practices prevailing in the community. Lastly, it concludes the significant role played by many players ensuring perseverance of indigenous community-based knowledge and practices with a blend of modern FPC. The similar success stories would build confidence among the ethnic group of the different region to participate in formalizing the agriculture sector.

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REFERENCES

Adhikari B, Williams F, Lovett JC (2007) Local benefits from community forests in the middle hills of Nepal, Forest Policy and Economics 9: 464-478.

Bhattacharjee, S. (2010). Experience of producer organizations: A case of five producer companies. Financing Agriculture, 42(7), 12-12. Bikkina N, Turaga R.M.R. & Bhamoriya V. (2017). Farmer Producer Organizations as farmer Collective: A case study from India, Development Policy Review, 36, 669687.

Census of India: Provisional Population Tables – Census 2011" (PDF). Censusindia.gov.in. Archived from the original (PDF) on 9 April 2011. Retrieved 11 April 2011. Chandra A, Saradhi P, Maikhuri RK et al., (2011).Traditional Agrodiversity Management: A case study of central Himalayan village Ecosystem. Mt Sci, 8, 62-74.

Chand R., Prasanna, P.L., and Singh, A. (2011). Farm Size and Productivity: Understanding The strengths of Smallholders and Improving Their Livelihood, Economic and Political Weekly, 46(26), 5-11.

Choudhury, S., Pant, R.M., Chatterjee, S., Nanding,A. (2016). Destination branding of Ziro through potentiality of bio tourism, Bioprospecting of Indigenious bioresources of North-East India,329-337.

Das A, and et al., (2012). Natural resource conservation through indigenous farming system: wisdom alive in North East. Indian Journal of Traditional Knowledge, 11(3), 505-513.

Desai, R.M., Joshi S. (2014). Fram Size and Productivity: Understanding The Strengths of Smallholders And Improving Thier Livelihoods, Economic and Political Weekly, 46(26), 5-

12.

Dollo M., Samal, P.K., Sundriyal, R.C., Kumar, K. (2009). Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalaya, India. Journal of American Science, 2009; 5 (5): 41-52.

Elwin V, (2012). Myths of the north east frontier of India. Elwin V, (2014). Democracy in NEFA. Fischer, E., & Qaim, M. (2012). Linking smallholders to markets: Determinants and impacts of farmer collection action in Kenya. World Development, 40, 1255-1270. https://doi.org/10.1016/j.worlddev.2011.11.018.

Gangwar, A.K. and Ramakrishnan, P.S. (1989) Cultivation and use of Lesser known Plants of Food value by Tribals of North-East India. Agriculture, Ecosystem and Environment, 25: 253 - 267.

Hilaly S,(2018). Culture of Friendship Among the Apatanis of Arunachal Pradesh, space and Space and Culture, India 2018, 6:1 https://doi.org/10.20896/saci.v6i1.322

Kumar A, Ramakrishnan P S., (1990), Energy Flow through An Apatani Village Ecosystem of Arunachal Pradesh in North-East India, Hum Ecol, 315.

Mondal, A. (2010). Farmers' producer company (FPC) concept, practices and learning: A case from action for social advancement. Financing Agriculture, 42(7), 29-33.

Murtem G, Das AK.,(2005). Traditional Medicinal Plants of Nyishi tribes of Arunachal Pradesh, Arun For News, 21(1, 2): 31.

Nabam, N. (2013). Customary Laws of Nyishi tribe in India. International Journal of Advance Research, IJOAR.ORG, 1,7. Poffenberger, M. (editor) (2005) Community Forestry in North-East India. Community Forestry International, Inc., South Lake Tahoe, USA. Shankar R, Tripathi AK, Neyaz S, Gyati A, Rawat MS, Dhiman KS.(2015). Distribution of Medicinal Plants in Kurung Kumey,East Kameng and West Kameng Districts of Arunachal Pradesh: Their Systemic Conservation. World Journal of Pharmaceutical Research, 04(09), 977-993.

Sharma UC, Prasad RN (1994) Potential indigenous farming systems of North Eastern Hill region,ICAR Research Complex for NEH Region, Shillong. 48p. Shelar, A. (2012). Making of a Farmers' company: Avirat Agro Business Producer Company Limited. In Strengthening Civil Society Participation in Natural Resource Management: Experience of sajjata sang- NGOs in Gujarat, 60-71. Singh, S. (2012). New Markets for Smallholders in India: Organization and Governance, Economic and Political Weekly, 47(52), 95-106. https://www.jstor.org/stable/41720555.

Trebbin, A. (2013). Linking Small Farmers to Modern Retail Through Producer Organizations: Experiences with Producer Companies in India. Food Policy, 45, 3544.

Ramya T. (2012). Brief Mythology of Longte-Yullo Festival of The Nyishi Tribe, Asian Journal of Research in Social Sciences and Humanities Year : 2012,Volume : 2, Issue : 6 First page : (9) Last page : (14) Online ISSN : 22497315.

Rai, SC. (2007). Traditional Ecological Knowledge and Community-Based Natural Resources Management in North-East India, Journal of Mountain Science, 4(3), 248-258. Doi. 10.1007/S11629-007-0248-4. Welsh, R. (1997). Vertical Coordination, Producer Response, and Locus of Control over Agriculture Production Decision, Rural Sociology, 62, 419-507. https:// doi.org/10.1111/j.1549-0831.1997.tb00661.x.

Reinforcing Livelihood by Interdependency of HR Capacity-ICT: Relevance to Multi-cropping practice system in Indian Eastern Himalaya

Reinforcing Livelihood by Interdependency of HR Capacity-ICT: Relevance to Multi-cropping practice system in Indian Eastern Himalaya

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Abstract. The rural economy of Eastern Himalayan region of India is mostly agriculture based, dominated by traditional as well as community knowledge, has been using as source of livelihood since long years back. But with Green evolution and technological advancement, High Yielding variety of cash crop like Large Cardamom (Amomum subulatum Roxb.) and influence of skill-information-technology are emerging in a great extent respectively only to ensure sustainable livelihood. Since it is seen that only through large cardamom cultivation, it is difficult to ensure sustainability, hence concept of Multicropping is very much demanding. Here, this paper highlights the influence and interdependency of Human Resource Capacity and Information and Communication Technology (ICT) on Multicropping as well as on large cardamom cultivation to ensure sustainable livelihood in this particular region.

Key words: Large Cardamom, Multicropping, ICT, HR capacity building

1. Introduction

Multicropping practice as a part of Agricultural Development in the country like India where more than 121 cr. population is the utmost requirement to challenge sustainability, livelihood and food security. Here the agricultural development talks about all round development i.e. crop pattern, technology skills etc. and it can be understood as transition from cultural historical based rural production and marketing norms to structural farming of small and marginal farmers into a global market through integration [1-5]. In agricultural development information-intensive, knowledge-intensive production and marketing practices are the key elements [5-7]. On the other side, the technological advancement, the Information and Communication Technology (ICT) is introducing a new era in the field of agriculture specially in two broad areas, one is Market Efficiency and the other one is Knowledge Dissemination through mobile devices, remote sensors etc. [5-7], [24-25]. Market efficiency talks about the coordination on agricultural inputs, market information, financial transaction, e-commerce platform etc. whereas the Knowledge Dissemination focus on disseminating knowledge to small and marginal farmers on contemporary technologies which can uplift production practice, food security, sustainability and welfare [5], [7-10]. In the rural economy of Eastern Himalayan region of India, the cultivation of Large Cardamom (Amomum subulatum

Roxb) as a High Yielding Variety (HYV) of cash crop is much popular as one of the main sources of livelihood [11-15]. But these days due to varied challenging dimensions of land resource, climate, different crop diseases etc. compelling to go for multi-cropping practice along with the interdependency of ICT [16-17],[21], [23-25]. By focusing on Sustainability, it is very high in demand to coordinate among Large Cardamom cultivation along with Multicropping practice, ICT interdependency and Capacity building as only cultivation of Large Cardamom cannot ensure sustainability [1-2],[18],[24],[26]. Due to its high demand both in national and international market, its glamour among the cultivators is still very high [27]. If capacity building on manpower and ICT interdependency goes hands on together in agricultural sector, obviously it will bring a new era after the Green revolution [8], [19-20], [22]. This paper discusses necessity and importance of ICT interdependency along with interdependency of Human Resource (HR) Capacity Building with the objectives: i) To discuss the scenario of large Cardamom cultivation along with Multicropping practice in the region and ii) To discuss the interdependency of ICT as well as Capacity Building of manpower to ensure Sustainability. Here the paper is discussed in four sections, namely 1. Introduction 2. Research Methodology 3. The Case study 4. Conclusion. The first section "Introduction" part contains the current scenario of agricultural sector along with the need of some interdependency of ICT and Capacity building of HR to ensure sustainable livelihood. The "Research Approach" of this study includes Methodology, Study area, sampling and techniques. The Case study section is discussed in i) Current Scenario on livelihood practice in Himalayan region ii) In present context the Small and Marginal farmers' livelihood practice iii) Importance of ICT and Capacity Building of Manpower for cultivation of Large Cardamom iv) Planned outline reinforcing Livelihood of marginal farmers. The last section "Conclusion" summarizes the discussion of the paper in brief highlighting the future scope.

2. Research Methodology

2.1 Methodology

A qualitative approach is adopted for this research work which comprises both primary as well secondary data. For the collection of primary data, methods and tools that were adopted are structured questionnaire, personal interviews and for data validation purpose personal observation was used. The secondary data were collected from different sources like department of Horticulture, Government of India, spice board journal, annual reports of government of India: Ministry of Small and Medium Enterprises (MSME), Census India 2011, different business news, Ministry of Rural Development, United Nations Educational, Scientific and Cultural Organisation (UNESCO) etc. The combination of both judgement and convenient sampling techniques were used. The sample size for this study was 49 which represent almost 78% of total registered Large cardamom cultivators in Lower Subansiri.

2.2 Study area and sampling

Majority of the respondents which represent 80% of total sample size belong from Yachuli (Zero-II) as the majority habitants are aggressively associated with large cardamom cultivation and very few which represent only 20% of total sample size belong from Zero-I as the habitants are transforming themselves towards Kiwi cultivation gradually. The sample highlights a unique characteristic that involvement of young generation is not found active whereas the registered farmers belong from more than 35 years of age group. Though the farmers are associated with this cultivation from last many years but professional engagement only from last 3-9 years. A new ray is coming among the women who have registered as large cardamom cultivators though its size is small.

3. The Case Study

3.1 Current livelihood practice in Himalayan region

Most of the habitants of Lower Subansiri engage with vegetation of Maize, Pumpkin, Potato, Ginger, Chinese cabbage, Pisciculture along with rice cultivation etc. in large scale through Multicropping practice as major source of livelihood which are completely traditional practice based without any interdependency of ICT. Along with these cultivations almost every household maintain their own kitchen garden as a community practice. The traditional cum manual based cultivation is mostly done by the help of both hired labours as well as family members. Recently the emergence of formalized cooperative farming concept is grazing among the cultivators of Yachuli which can be used in an extensive manner to enhance the value chain in a global market.

3.2 In present context the Marginal farmers' livelihood practice

The marginal farmers do the Multicropping practice with vegetation and animal husbandry to meet the day to day expenditure but they go for large cardamom cultivation to meet the high demands of life i.e. of education of children and medical expenditure of family members.

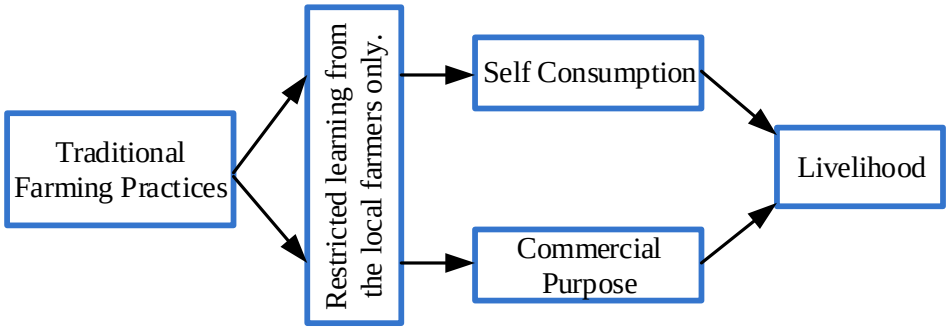

Figure 1. Diagrammatic representation of Existing practice of Livelihood by Marginal Farmers

Figure 1. highlights the traditional farming practice only that are being followed by the marginal farmers to ensure livelihood through Multicropping as well as large cardamom cultivation without any interdependency of ICT and change agent. With the advantage of geographical location and restricted learning from neighbour as well as from local farmers, the habitants go for Multicropping along with large cardamom cultivation. The ultimate production is used for both self - consumption and Commercial purpose as source of their livelihood. But gradually regions' climatic condition is changing due to slight increase in population, life style etc. Almost all the respondents of marginal farmers agreed and do believe that only to ensure sustainability they go for Large cardamom cultivation. Most importantly the marginal farmers are adopting its commercialization from last few couple of years which is great sign for them as well as for the economic condition of the place.

3.3 Importance of ICT and Capacity Building of Manpower for cultivation of Large Cardamom

The traditional as well as community-based knowledge and information from friends and relatives were the main sources of information based on which cultivation of Large cardamom is done commercially by the marginal farmers. But to sustain in the competitive global market with value chain it is very difficult without enhancing the use of ICT as well as building capacity of manpower on this regard. So, interdependency of ICT and Capacity building of manpower in the form of skill upgradation are the utmost requirements to challenge the global requirements either by the government agencies or by some non- government organisation by considering the gap. As it is coming to know that Government organise some kind of awareness programme on large cardamom cultivation in a very rare scale and some kind of training session only on cultivation process which is not even upgraded one only for the beneficiaries. So here it will be worth mentioning that

interdependency of ICT will enhance the farmers on keeping updated on Market Efficiency like updated agricultural inputs, market information; scientifically proved cultivation practice to get more success and most importantly on financial transactions where farmers lack knowledge. In addition to this ICT helps in Knowledge Dissemination to marginal farmers on contemporary technologies which can uplift production practice. At the same time if capacity building of manpower on those areas, which are already being covered by ICT, are done practically it will enhance the farmers into a such level which will give them the strength to face global challenge.

3.4 Planned outline reinforcing Livelihood of marginal farmers

The existing practice model is not acquainted with ICT as well as with Capacity Building of manpower which make the marginal farmers weaker in accepting the global challenges with value chain. So, all the challenges can be categorised in four broad parts. They are- a) Challenges with the Cultivation i.e. in-depth physiological knowledge about the plant as well as its sapling, its cultivation, plant's various diseases based on climatic ailment etc. b) Challenges with Manpower Ability i.e. handling technique from plant to supply of raw material which includes acquiring entrepreneurial skill, branding the farmers and their product by themselves, pricing strategy in between etc. c) Challenges with Climatic Condition which talks about the changing pattern of required climate like temperature, rain water, soil pattern, shading pattern, land structure, forestry knowledge etc. d) Challenges with ICT and Capacity Building i.e. how much the marginal farmers are updated with latest Agri- input technologies, latest market information, financial resources and transactions, e-commerce platform etc. with the involvement of local community.

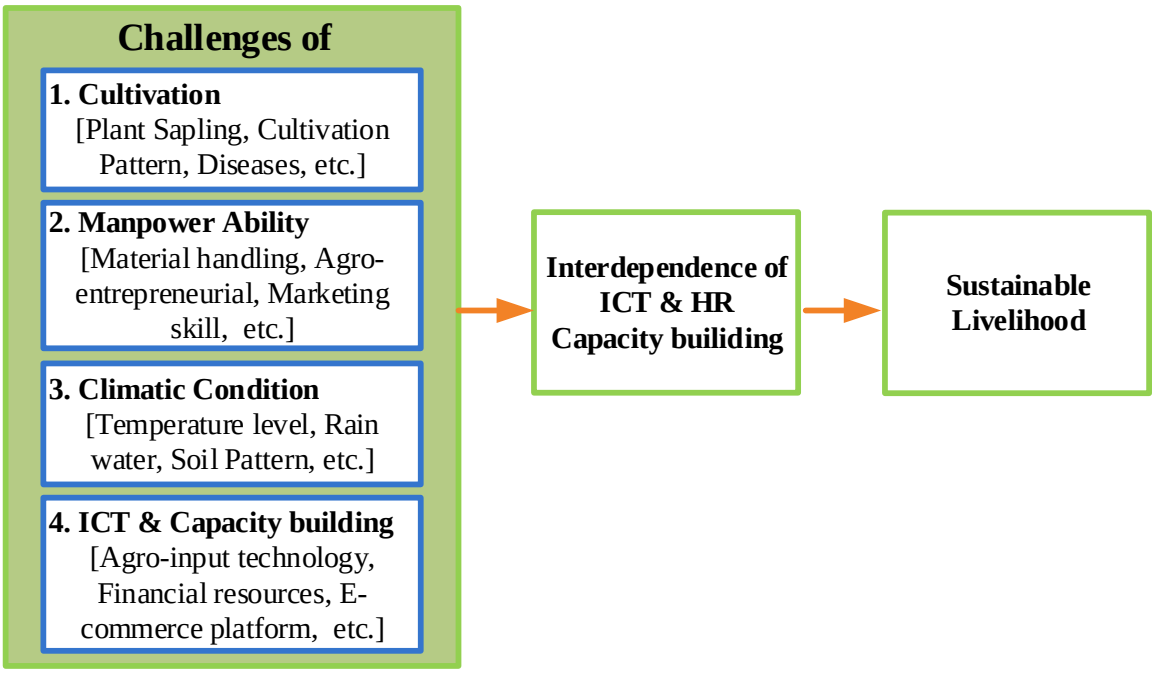

Figure 2. Proposed Planned outline reinforcing Livelihood of marginal farmers

Figure. 2 on Proposed outline on Sustainable Livelihood for marginal farmers is addressing on these issues so that sustainability of marginal farmers can be ensured through the interdependency of ICT and HR capacity building.

The proposed framework is talking about the high level of importance on the interdependency of ICT along with local community knowledge to enhance value chain on each and every stage of cultivation as well as to the stage of final product, and the interdependency of HR capacity building to enhance the ICT in reality through practical utilization in the field of agriculture more specially with the large cardamom cultivation. In short, if ICT and HR capacity building initiative are adopted parallelly

either by Government agencies or by the Non- government agencies with the support of Government or the cooperative farmers group (since it is emerging in the proposed area) all the four mentioned challenges area can be addressed by the marginal farmers through a proper coordination and linkage.

4. Conclusion

This paper has highlighted the importance and influencing capacity of ICT and HR capacity building along with community-based knowledge for agricultural development for sustainability of rural economy. Effective coordination and implementation among the four dimensions of challenges of marginal farmers would help in strengthening the farmers towards the global competition, also can address the sustainability of livelihood through large cardamom cultivation and Multicropping practices in the proposed region with satisfactory result.

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References

[1] Pothula A. L., Singh, A.I. (2013). Postharvest Processing of Large Cardamom in the Eastern Himalaya: A review and Recommendations for increasing the sustainability of a Niche crop. *Mountain Research and Development (MRD),* vol. 33, no. 4, November, 2013, pp. 453-462, https://doi.org/10.1659/MRD-JOURNAL-D-12-00069.1

[2] Opolot N. H, Isubikalu et. all (2018). Influence of university entrepreneurship training on farmers' competences for improved productivity and market access in Uganda". *Cogent Food & Agriculture*.

[3] Eva D., Artemis K. (2007). Capacity Building in Agricultural Biotechnology in Turkey. *Food Reviews International*, vol. 19, no. 4, pp. 437-445, DOI: 10.1081/FRI-120025484.

[4] Durugkar S., & Poonia C. R. (2017). Optimum utilization of natural resources for home garden using wireless sensor networks. *Journal of Information and Optimization Sciences,* 38:6, 1077-1085.

[5] Karanasios S., & Slavova M. (2016). How to development actors do "ICT for development"? A strategy-as-practice perspective on emerging practices in Ghanaian agriculture. *Information Systems Journal,* 29:888-913.

[6] Zewge A., & Dittrich Y. (2017). Systematic Mapping Study of Information Technology for Development in Agriculture (The Case of Developing Countries). *The Electronic Journal of Information Systems in Developing Countries,* vol. 82, no. 2, pp. 1-25.

[7] Lindlom J., Lundstrom C., et. all. (2017). Promoting Sustainable intensification in precision agriculture: review of decision support systems development and strategies. *Precision Agriculture,* 18:309–331, DOI 10.1007/s11119-016-9491-4.

[8] Blasi et. all. (2015). Alternative food chains as a way to embed mountain agriculture in the urban market: the case of Trentino. *Agricultural and Food Economics,* DOI 10.1186/s40100-014-0023-0

[9] Ahmed et all. (2017). Cropping systems diversification, improved seed, manure and inorganic fertilizer adoption by maize producers of eastern Ethiopia. *Journal of Economic Structures,* DOI 10.1186/s40008-017-0093-8.

[10] Johnson et all. (2015). The Capacity Building Experience of Women Engaged in Determining the Cost and Affordability of Healthy Food in Nova Scotia, Canada. *Journal of Hunger & Environmental Nutrition,* DOI: 10.1080/19320248.2014.962769.

[11] Sen S. and Kansal A. (2019). Integrating value-chain approach with participatory multi-criteria analysis for sustainable planning of a niche crop in Indian Himalayas. *Journal of Mountain Science*, vol. 16, no. 10, pp. 2417-2434.
[12] Sharma E. (2000). A Boon for Mountain Populations: Large Cardamom Farming in the Sikkim Himalaya. *Mountain Research and Development,* Vol. 20, No. 2, pp: 108-111.
[13] Sharma G. (2016). Declining Large-Cardamom Production Systems in the Sikkim Himalayas Climate Change Impacts, Agro economic Potential, and Revival Strategies. *Mountain Research and Development,* Vol. 36, No. 3, pp: 286-298.
[14] Sharma G. (2002). Performance of an Age Series of Alnus-Cardamom Plantation in the Sikkim Himalaya: Productivity, Energetics and Efficiency. *Annals of Botany,* pp: 261-272
[15] Dauda A. K., (2017). Gender capacity building needs on soil fertility management practices among smallholder arable crop farmers in Kwara State, Nigeria.
[16] Ferreroa G., et. all (2019). Capacity building and training approaches for water safety plans: A comprehensive literature review. *International Journal of Hygiene and Environmental Health,* vol. 224, no. 4, February, pp. 615-627, doi: 10.1016/j.ijheh.2019.01.011
[17] Kamruzzaman M., Takeya H. (2008). Influence of Technology Responsiveness and Distance to Market on Capacity Building. *International Journal of Vegetable Science,* vol.14, no. 3, pp. 216-231, DOI: 10.1080/19315260802164848.
[18] Sendegeya A.M (2016). The role of academia in capacity building for sustainable energy development: the case of Namibia. *Energy,* pp: 218-222.
[19] Ahmed M. H., Mesfin H. M. (2017). The impact of agricultural cooperatives membership on the wellbeing of smallholder farmers: empirical evidence from eastern Ethiopia. *Agricultural and Food Economics.*
[20] Babu S. C. et. all. (2015). Strengthening Capacity for Agribusiness Development and Management in Sub-Saharan Africa. *Africa Journal of Management,* ISSN: 2332-2373
[21] Choudhury S., Pant R.M. et. all. (2016). Destination Branding of Ziro Through Potentiality of Bio-tourism. *Bioprospecting of Indigenous Bio-resources of North-East India*, pp. 329-337, DOI: 10.1007/978-981-10-0620-3_21
[22] Sendegeya A.M (2016). The role of academia in capacity building for sustainable energy development: the case of Namibia. *Energy,* pp: 218-222.
[23] Johnson C. P., Williams P. L. et. all (2016). The Capacity Building Experience of Women Engaged in Determining the Cost and Affordability of Healthy Food in Nova Scotia, Canada. *Journal of Hunger & Environmental Nutrition*, vol. 10, no. 3, 14th pp. 356-378. Journal Database, http://dx.doi.org/10.1080/19320248.2014.962769.
[24] Gangopadhyay P. K., et. all. (2019). Spatial targeting of ICT-based weather and agro-advisory services for climate risk management in agriculture. *Climatic Change,* 154:241-256, doi.org/10.1007/s10584-019-02426-5.
[25] Aker J. C., et. all. (2016). The promise (and pitfalls) of ICT for agriculture initiatives. *International Association of Agricultural Economists,* DOI: 10.1111/agec.12301.
[26] S. K. Ghosh, A. K. Das and S. Choudhury, (2020) ICT Interventions in Rural Development Schemes: A Case of Rupshi Development Block, Assam, *2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2020, pp. 349-354, doi: 10.1109/ICRITO48877.2020.9197987.*
[27] J.H. Boruah, R.M. Pant, S. Choudhury, (2020), Sustainable livelihood by HR capacity building in multicropping practices of Indian Eastern Himalayan region: A case study, Journal of Statistics and Management Systems, 23, pp-277-284, https://doi.org/10.1080/09720510.2020.1724626

Evaluation of energy efficiency and moisture diffusivity for convective drying of large cardamom

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Evaluation of energy efficiency and moisture diffusivity for convective drying of large cardamom

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Abstract: The drying behavior of freshly harvested large cardamom capsules were studied in a hot air dryer within the temperature range of 50-80°C. The study on drying rate showed that the constant rate drying period was very short, and capsules mostly followed the falling rate drying period. The drying during falling rate drying was followed unsteady state mass transfer and was governed by Fick's diffusion law. The drying rate was faster initially when the moisture content in the product was high but with a decrease of moisture content, the drying rate was found to be decreased. Nine different drying kinetics models were fitted to find the best suitable model to predict the drying kinetics of large cardamom capsules. The two-term model was the best-suited model out of the nine different models, representing the drying properties of large cardamom with the highest R^2 and the lowest RMSE and χ^2 values. The maximum effective moisture diffusivity D_{eff} value of 3.898×10^{-10} was obtained at a drying temperature of 80°C, while the lowest value was 1.949×10^{-10} at 50°C. The dependency of effective moisture diffusivity with drying temperature was correlated by Arrhenius equation. The activation energy showing the minimum energy needed to extract moisture from a solid matrix of large cardamom capsule was calculated as 32.54 kJ/mol and the pre-exponential factor of Arrhenius equation was calculated at 7.6×10^{-4} m^2/s.
Keywords: large cardamom; thin layer drying; effective moisture diffusivity; activation energy.

1. Introduction

Drying is basically a simultaneous heat transfer and mass transfer process. The heat needed for the evaporation of moisture was supplied from the hot air circulating around the product. During the process, moisture from the product was transferred to the surrounding hot air during the drying process. Diffusion is a characteristic activity of drying materials and the transfer of water vapor from the inside of the food material to the outer surface during drying is controlled or regulated by the diffusion process. Drying requires the simultaneous transfer of heat and mass. Drying is primarily aimed at reducing moisture present in the product to enhance storage stability. Therefore, drying of fruits and vegetables has been done as a way of enhancing storability.

Large cardamom has a leading role among different spices and has immense commercial significance. Large cardamom (*Amomum subulatum Roxb*. Family: Zingiberaceae) is the value-added cash crop and the primary source of cash income for eastern Himalayan farmers. It is also known as black cardamom, and reinforces and intensifies the recipes' taste. The main production centers in India are the sub-Himalayan ranges of Arunachal Pradesh, a part of Nagaland, Sikkim and Darjeeling district of West Bengal. Drying is the most critical operation after harvesting the large cardamom. The cardamom capsule moisture content has to be reduced to a safe level for a longer storage period. Proper drying will maintain the quality of the product and minimize losses. Delays in drying, inadequate drying, or ineffective drying may decrease the consistency of the capsule and cause losses.

Drying results in a substantial decrease of space demand for storage of the commodity for longer length. The different drying methods implemented for drying of fruits and vegetables includes tray drying, vacuum drying (Khawas et al., 2016), microwave drying (Dash and Das, 2020; Dash and Das, 2019a), microwave vacuum drying (Raj and Dash, 2020; Dash, Chakraborty, and Singh, 2020), osmotic drying (Prithani, and Dash, 2020; Dash and Balasubramaniam, 2018), and fluidized bed drying (Dash and Das, 2019b). The prediction of drying behavior can be obtained from suitable drying models. The drying of different food products was predicted through different drying model in different food products such as onions (Singh and Sodhi, 2000), green bean (Doymaz, 2005), hawthorn fruit (Sousa et al., 2018), ear corn (Friant et al., 2004), apricots (Doymaz, 2004a), and mulberry (Doymaz, 2004b) are available. Each food material has unique behavior due to the difference in structure and composition. The drying kinetics study can be implemented to design suitable dryers and optimize the drying parameters (Kingsly et al., 2006). The different thin-layer drying kinetics model studied for drying of food materials are toria seeds (Rangroo and Rao, 1992), dates (Hassan and Hobani, 2000), chilli pepper (Tunde-Akintunde and Ajala, 2010), millet samples (Ojendiran and Raji, 2010), srilankan paddy (Syamali et al., 2009), sesame seeds (Khazaei and Daneshmandi, 2007), amaranth grain (Ronoh et al., 2010), and parboiled wheat (Debabandya et al., 2005). The different kinetic models were implemented to evaluate the effective moisture diffusivity of the product. The effective moisture diffusivity obtained at different temperature were implemented to evaluate the activation energy in different products such as star fruit (Dash, Gope, Sethi, and Doloi, 2013), kachkal banana peel (Khawas et al., 2014), ripe Jackfruit (Saxena and Dash, 2015), culinary banana slices (Khawas et al., 2015), and elephant apple (Nag and Dash, 2016). However, a very limited study had been conducted on the drying of freshly harvested spices like large cardamom. Based on this, the objective of the study was to observe the drying behavior of freshly harvested large cardamom. Different thin layer model was fitted to the drying data to obtain the most suitable model to represent the kinetics behavior of the drying process. The effective moisture diffusivity and activation energy for the process was evaluated.

2. Materials and method

2.1. Drying procedure

The freshly harvested large cardamom capsules of Arunachal Pradesh, Itanagar, were collected from local farmers. Freshly harvested cardamom capsule has a moisture content of 78.59±3.65 percent (wet basis). The raw material was dried immediately by hot air drying until it reaches a moisture content (8.2±0.5 percent wet basis). The drying experiments were conducted using a laboratory tray dryer at a specific temperature. The moisture loss due to drying was recorded during the experiment with the aid of an electronic balance.

2.2. Mathematical modeling

The drying of large cardamom was conducted at four different temperatures, such as 50, 60, 70, and 80°C. The moisture content during the drying was obtained at an interval of 30 min. The obtained moisture content was expressed in dimensionless moisture ratio as presented in Eqn. (1).

$$\mathrm{MR} = \frac{Mt-Me}{Mo-Me} \qquad (1)$$

In Eqn. (1) the parameterMR, M_t, M_o, M_e are expressed in terms of kg water/kg dry matter) and the parameters are defined as follows.

$\mathrm{MR} =$ Moisture Ratio

$\mathrm{M_t} =$ Moisture content at time $\mathrm{t} = \mathrm{t}$

$\mathrm{M_o} =$ Initial moisture content at time $\mathrm{t} = 0$

$\mathrm{M_e} =$ Equilibrium moisture content at time $\mathrm{t} = \infty$

The dimensionless moisture ratio was fitted with different models present in Table (1).

2.3. Estimation of Effective Moisture Diffusivity

The drying of biological material such as fruits and vegetables follows the falling rate period. The drying process follows the falling rate period was generally described by Fick's second Law of mass transfer, as shown in Eqn. (2)

$$\partial M/\partial t = D_{eff}\, \partial^2 M/\partial x^2 \quad (2)$$

The large cardamom capsule was considered as geometrically spherical in shape and hence, the solution of diffusion models for spheres was applied. The different assumptions were:

i. Initial moisture content across the fresh capsule was uniform.
ii. The capsule was believed to be homogeneous and isotropic solids and the transition of mass to the core was symmetric.
iii. The moisture was assumed to be dispersed uniformly across the cardamom capsule in the initial state (i.e., at time t=0)
iv. Thermal equilibrium occurs between the capsule surface and the drying air.
v. The coefficient of diffusion is constant, and the shrinkage is negligible.
vi. Migration of moisture is by diffusion only.

The solution of Eqn. (2) for spherical geometry is presented in given Eq. (3) (Crank, 1975).

$$MR = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(n)^2}\, exp^{\frac{\left[-(n)^2\pi^2 D_{eff}\, t\right]}{r^2}} \quad (3)$$

Where r = radius of the cardamom capsule. On neglecting the higher order terms, the equation (3) reduces to Eqn. (4).

$$MR = \frac{6}{\pi^2}\, exp^{\frac{[-\pi^2 D_{eff}\, t]}{r^2}} \quad (4)$$

Taking natural logarithm on both sides of Eqn. (4) the obtained equation is presented in Eqn. (5).

$$\ln MR = \ln\frac{6}{\pi^2} - \frac{[\pi^2 D_{eff}\, t]}{r^2} \quad (5)$$

The slope of the graph plotted between ln(MR) and drying time would be used to calculate the effective moisture diffusivity of the product during drying.

$$slope = \frac{[-\pi^2 D_{eff}]}{r^2} \quad (6)$$

$$D_{eff} = \frac{-slope\, r^2}{\pi^2} \quad (7)$$

The effective moisture diffusivity was correlated with different drying temperatures by using the Arrhenius equation to obtain the activation energy (Wang et al., 2018).

$$De = Do\, exp\left(\frac{E_a}{RT}\right) \quad (8)$$

$$\ln De = \ln Do - \frac{E_a}{RT} \quad (9)$$

In Eqn. (8) and (9), the parameters E_a, R, T, and D_o are defined as following.

$E_a = Energy\ of\ activation\ (kJ/mol)$
$R = universal\ gas\ constant\ (8.3143\ kJ/mol)$
$T = absolute\ air\ temperature\ (K)$
$D_o = preexponential\ factor\ of\ the\ Arrhenius\ equation\ (m^2/s)$

The activation energy represented the minimal energy to be supplied in order to disrupt the interactions between water-solid or water-water and transfer water molecules in the solid from one point to another point within the solid. The smaller activation energy indicated that the water molecule could pass in the sample more readily. The activation energy needed for the initiation of drying was determined using the Arrhenius equation.

2.4. Statistical analysis

The different statistical parameters such as coefficient of determination (R^2), chi-square ($\chi 2$), and root mean square error (RMSE) were evaluated to select the best suitable model to represent the drying kinetics. The best suited model was chosen based on the highest R^2 and lowest ($\chi 2$) values (Khawas et al.,2016; Togrul and Pehlivan, 2002). R^2 value indicates the correctness in fitting and χ^2 and RMSE value indicates bias error, i.e., deviation in the fitting.

Table 1: The Different mathematical models applied to the experimental data

Model No.	Model Name	Model	References
1	Newton	$MR = exp(-kt)$	Westerman et al., 1973
2	Page	$MR = exp(-kt^n)$	Page, 1949
3	Modified page	$MR = exp[-(kt)^n]$	Yaldiz et al., 2001
4	Henderson and Pabis	$MR = a\,exp(-kt)$	Yagcioglu et al., 1999
5	Logarithmic	$MR = a\,exp(-kt) + c$	Yaldiz and Ertekin, 2001
6	Verma et al.	$MR = a\,exp(-kt) + (1 - a)exp(-gt)$	Verma et al., 1985
7	Wang and Singh	$MR = Mo + at + bt^2$	Ozdemir and Devres,1999
8	Two term	$MR = a\,exp(-k_o t) + b\,exp(-k_1 t)$	Rahman et al., 1998
9	Two term exponential	$MR = a\,exp(-kt) + (1 - a)exp(-kat)$	Yaldiz et al., 2001

3. Results and Discussions

3.1. Drying behavior of large cardamom

The variation of moisture ratio of large cardamom at four different drying temperatures is 50, 60, 70, and 80°C, as shown in Fig. (1). It was observed that the moisture content of the product was reduced at a faster rate during the initial drying period. The moisture content curves were complex in nature. The rate of moisture loss was higher with an increase in drying air temperature, causing a reduction in drying time to attain a particular level of moisture content. The faster moisture vaporization at higher temperatures was due to an increase of vapor pressure with the product at an elevated temperature level. In addition to this, the relative humidity of drying air also decreases with an increase in temperature, causing an increased moisture removal rate. The equilibrium moisture content of the cardamom capsules within the temperature was 50-80°C were 6.29-8.75 kg/kg dry matter. With an increase in drying air temperature, the relative humidity of drying air was decreased. Lowe relative humidity at higher temperatures was able to reduce the equilibrium moisture content to a lower level. The time taken to attend a particular moisture content was decreased by 16.4 % and 11.2 % when the drying temperature was increased from 50 to 60°C and 60 to 70°C, respectively.

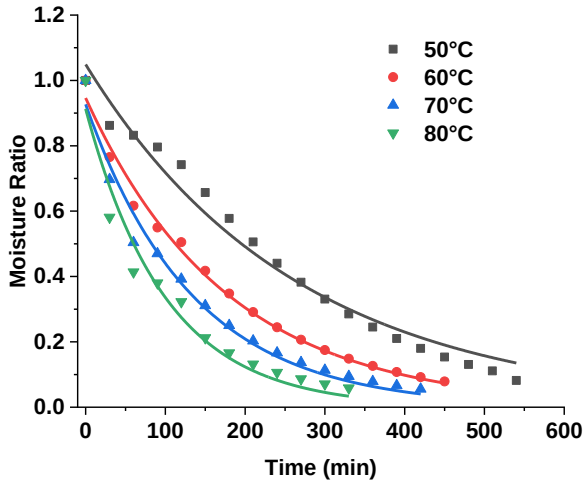

Fig.1: Plot of moisture ratio and time of large cardamom at different temperatures

3.2. Fitting of drying model for drying of large cardamom

The drying constants, root mean square error (RMSE), reduced chi-square value (χ^2) and coefficient of determination (R^2) were calculated for all the nine models at 50, 60, 70, and 80°C. The obtained values of R^2 and χ^2 and RMSE for different models are presented in Table (2). The most suitable model capable of predicting the drying of large cardamom was selected based on the highest R^2 and lowest RMSE and χ^2 values.

Fitting moisture ratio data in Newton model within the temperature range of 50-80ºC had the R^2, χ^2 and RMSE values of 0.952-0.987, 0.003-0.021, and 0.03-0.06 respectively. The k value for newton model was found to increase from 0.0036 to 0.01108 with an increase of temperature from 50-80ºC. Moisture ratio data fitting in the 50-80ºC temperature range for Page model had the R^2, χ^2 and RMSE values of 0.971-0.994, 0.0106-0.0314, and 0.0190-0.0249 respectively. The k value for the Page model was found to rise from 0.0007 to 0.0483 with a temperature increase from 50-80ºC. Moisture ratio results fitting in the Modified Page model within the 50-80ºC temperature range resulted in the R^2, χ^2, and RMSE values of 0.951-0.994, 0.0104-0.0260, and 0.0190-0.0249 respectively. The k value for Modified Page model was found to rise from 0.00359 to 0.01243, with a temperature increase from 50-80ºC. Fitting of moisture ratio data in Henderson and Pabis model within the temperature range of 50-80ºC had the R^2, χ^2, and RMSE values of 0.960-0.991, 0.0106-0.0213, and 0.0238-0.0520 respectively. The k value for Henderson and Pabis model was found to increase from 0.00379 to 0.01001 with an increase of temperature from 50-80ºC. Moisture ratio fitting of the Logarithmic model fitting within the 50-80ºC temperature range had R^2, χ^2, and RMSE values of 0.9621-0.9916, 0.0019-0.0203, and 0.0231-0.0432, respectively. The k value for the Logarithmic model was observed to increase from 0.00214 to 0.01326 with temperature increase from 50-80ºC. Fitting of moisture ratio data in Verma et al. model within the temperature range of 50-80ºC had the R^2, χ^2 and RMSE values of 0.9541-0.9972, 0.0106-0.0211, and 0.0133-0.0409 respectively. The k value for Verma et al. model was found to increase from 0.00392 to 0.00779 with an increase of temperature from 50-80ºC. Fitting of moisture ratio data in Wang and Singh model within the temperature range of 50-80ºC had the R^2, χ^2 and RMSE values of 0.873-0.984, 0.0097-0.0227, and 0.0215-0.1937 respectively. The k value for Wang and Singh model was found to increase from 0.00277 to 0.00768 with an increase of temperature from 50-80ºC. Fitting of moisture ratio data in the two-term exponential model within the temperature range of 50-80ºC had the R^2, χ^2 and RMSE values of 0.7593-0.9967, 0.0015-0.0176, and 0.0150-0.1371 respectively. The k value for the two-term exponential model was found to increase from 0.00523 to 0.0478 with an increase of temperature from 50-80ºC.

Table 2: Drying kinetics parameters of convective drying of large cardamom

Drying models	Temperature	Parameters	R^2	χ^2	RMSE
Newton	50	$k = 0.0036$	0.9738	0.0022	0.0474
	60	$k = 0.00602$	0.9872	0.0109	0.0305
	70	$k = 0.00809$	0.9752	0.0218	0.0426
	80	$k = 0.01108$	0.9526	0.0036	0.0600
Page	50	$k = 0.000724703$ $n = 1.2841$	0.9831	0.0106	0.0236
	60	$k = 0.01255$ $n = 0.86081$	0.9847	0.0204	0.0190
	70	$k = 0.02433$ $n = 0.78172$	0.9946	0.0314	0.0191
	80	$k = 0.0483$ $n = 0.69076$	0.9710	0.0107	0.0249
Modified page	50	$k = 0.00359$ $n = 1.28846$	0.9731	0.0260	0.0236
	60	$k = 0.00618$ $n = 0.86231$	0.9947	0.0116	0.0190

	70	$k = 0.00862$ $n = 0.78309$	0.9646	0.0104	0.0191
	80	$k = 0.01243$ $n = 0.69176$	0.9510	0.0107	0.0249
Henderson and Pabis	50	$k = 0.00379$ $a = 1.049$	0.9767	0.0120	0.0435
	60	$k = 0.00567$ $a = 0.94643$	0.9916	0.0106	0.0238
	70	$k = 0.00746$ $a = 0.92707$	0.9821	0.0213	0.0349
	80	$k = 0.01001$ $a = 0.91298$	0.9608	0.0130	0.0520
Logarithmic	50	$k = 0.00214$ $a = 1.36948$ $c = -0.36734$	0.9621	0.0107	0.0246
	60	$k = 0.00608$ $a = 0.93017$ $c = 0.02483$	0.9916	0.0106	0.0231
	70	$k = 0.00887$ $a = 0.9006$ $c = 0.05042$	0.9854	0.0211	0.0302
	80	$k = 0.01326$ $a = 0.87654$ $c = 0.07347$	0.9701	0.0123	0.0432
Verma et al.	50	$k = 0.00392$ $a = 1.08004$ $g = 2.2$	0.9781	0.0019	0.0409
	60	$k = 0.00532$ $a = 0.89145$ $g = 2.2$	0.9972	0.0112	0.0133
	70	$k = 0.00656$ $a = 0.82127$ $g = 2.2$	0.9958	0.0203	0.0161
	80	$k = 0.00779$ $a = 0.72266$ $g = 2.2$	0.9541	0.0104	0.0191
Wang & Singh	50	$a = -0.00277$ $b = 0.00000196201$	0.9843	0.0105	0.0215
	60	$a = -0.00477$ $b = 0.00000630586$	0.9628	0.0227	0.0502
	70	$a = -0.00584$ $b = 0.00000901659$	0.9194	0.0159	0.1739
	80	$a = -0.00768$ $b = 0.0000154222$	0.8730	0.0097	0.1937
Two term	50	$k_0 = 0.00392$ $k_1 = 1.9681$ $a = 1.08006$ $b = -0.08006$	0.9966	0.0020	0.0039
	60	$k_0 = 0.0053$ $k_1 = 0.10317$ $a = 0.8878$ $b = 0.11226$	0.9970	0.0002	0.0132

Two term exponential	70	$k_0 = 0.00635$ $k_1 = 0.06257$ $a = 0.7914$ $b = 0.20936$	0.9962	0.0003	0.0147
	80	$k_0 = 0.09586$ $k_1 = 0.00764$ $a = 0.29451$ $b = 0.70558$	0.9936	0.0005	0.0188
	50	$k = 0.00523$ $a = 1.82125$	0.9932	0.0106	0.0235
	60	$k = 0.04785$ $a = 0.11136$	0.9967	0.0102	0.0150
	70	$k = 0.00525$ $a = 0.99784$	0.7593	0.0176	0.1278
	80	$k = 0.04408$ $a = 0.2039$	0.9801	0.0015	0.1371

Among the different models discussed, two-term model had a most significant fitting of data in terms of average R^2 (0.998) and χ^2 (1.17×10^{-3}) values and hence proposed as the best model describing the drying behavior of large cardamom. Fitting of moisture ratio data in two-term model within the temperature range of 50-80°C had the R^2, χ^2 and RMSE values of 0.9936-0.9970, 0.0002-0.020, and 0.0039-0.0188 respectively. It was observed that among the four drying constants of two-term model, 'k_0' and 'b' increased with temperature while 'k_1' and 'a' decreased with temperature. The 'k_0' and 'b' value for the two-term model was found to increase in the range of 0.00392 - 0.0958 and 0.08006-0.70558 respectively whereas the 'k_1' and 'a' value was found to decrease in the range of 1.9681-0.00764 and 1.08006-0.70558 with the increase of temperature from 50-80°C.

3.3. Effective moisture diffusivity for drying of large cardamom

Predicted moisture ratios were plotted against time at different temperatures as 50, 60, 70, and 80°C to obtain the effective moisture diffusivity. From the respective slope, moisture diffusivity values were determined using Eqns. (6 and 7). The highest effective diffusivity (D_{eff}) value of 3.898×10^{-10} was obtained at drying temperature 80°C while the lowest value of 1.949×10^{-10} at 50°C (Table 3). The diffusivity for drying of different food was found to be in the same range as obtained for the convective drying of large cardamom. Effective diffusivity in the temperature range of 50 -120°C for rough rice and brown rice with the moisture content of 15 % (db) was observed to be 1.3×10^{-10} - 3.2×10^{-9} and 4.5×10^{-10} - 3.9×10^{-9} $m^2.s^{-1}$ respectively (Bakshi and Singh, 1980). Drying analyses of two types of millet i.e. SOSAT C88 and EXBORNO with an initial moisture content of 31.6±1% (wb) and 22.75±2.25% (wb) was conducted at drying temperatures of 40, 50, 60, and 70°C. The effective moisture diffusivity within the temperature range of 40-70°C was increased and the obtained values were in the range of 2.86×10^{-9} – 5.27×10^{-9} and 1.17×10^{-9} – 2.98×10^{-9} $m^2.s^{-1}$ respectively (Ojediran and Raji, 2010). A study of effective diffusivity of barley grain assuming the shape of the grain as spherical geometry showed that the diffusivity was varied in the range of 1.99×10^{-11} -5.31×10^{-11} $m^2.s^{-1}$ (Markowski et al., 2010). The hot air drying and vacuum drying of bee pollen within the temperature range of 40-50°C revealed that the two-term model was the most suitable model to predict the moisture ratio values. The effective moisture diffusivity values for drying bee pollen were varied between 8.40×10^{-11} - 6.29×10^{-10} m^2/s (Kayacan et al., 2018). The moisture diffusivity of red pepper was studied under three drying conditions such as hot air drying (HAD), infrared-assisted hot air drying (IAHD), and pulsed vacuum drying (PVD). The diffusivity values for HAD, IAHD, and PVD were varied between 1.33 –5.83×10^{-10}, 1.38–6.87×10^{-10}, and 1.75–8.97×10^{-10} m^2/s, respectively (Deng et al., 2018).

Table 3: Effective moisture diffusivities of black cardamom capsule at different temperatures

Temperature	D_{eff}	Ln D_{eff}	R^2	Chi Square
50°C	1.949×10^{-10}	-22.3583	0.866	0.0281
60°C	2.729×10^{-10}	-22.0219	0.913	0.0763
70°C	3.508×10^{-10}	-21.7706	0.953	0.0459
80°C	3.898×10^{-10}	-21.6652	0.959	0.0174

3.4. Activation energy for drying of large cardamom

In order to determine the pre-exponential component (D_o) and activation energy (E_a) of the Arrhenius equation (Eqns. 8-9), the logarithm of effective moisture diffusivities (Deff) was plotted against the reciprocal of absolute temperature (Fig. 2). From the intercept of linear fit equation (Eqn. 2), the value of D_o for large cardamom was evaluated as 7.61×10^{-4} m^2 s^{-1} and the value of E_a was found to be 32.55 $kJ.mol^{-1}$.

$$D_{eff} = (7.61 \times 10^{-4}) \exp\left(-\frac{32.55\times10^{3}}{RT}\right) \quad (10)$$

The amount of energy barrier that has to overcome i.e., the threshold barrier to activate the diffusion of moisture is the activation energy and the estimated activation energy value was 32.55 kJ / mol. The activation energy can be decreased by increasing the temperature and the drying rate, but the product quality can be degraded. The drying of *Phyllanthus amarus* and *Phyllanthus niruri* showed that an activation energy values of 22.828 and 43.129 kJ/mol, respectively (Sousa et al., 2018). The obtained results are similar to the results obtained in the drying of various food products such as apple with activation energy value 19.96 – 22.62 kJ mol^{-1} (Teixeira and Tobinaga, 1998), carrot with activation energy value 22.43 kJ mol^{-1} (Togrul, 2006) and red pepper with activation energy value 24.76 kJ mol^{-1} (Kaleemullah and Kailappan, 2005).

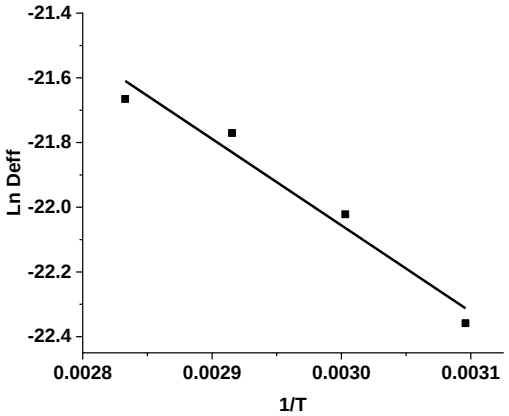

Fig.2: Relationship between the effective moisture diffusivities and temperatures

4. Conclusion

The drying behavior of larger cardamom was applied to nine different models in the literature to establish the drying kinetic model for the drying of large fresh cardamom. The two-term model delivered the best results among these models and showed good agreement with the experimental data obtained from the experiments, including the thin layer drying process. When the effects of drying air temperature on the constants and coefficients of the two-term model were examined, the R^2, $\chi 2$ and RMSE values were found to be in the range of 0.9936-0.9970, 0.0002-0.020, and 0.0039-0.0188 respectively. Therefore, the two-term model adequately described the drying behavior of large cardamom in the drying process within the temperature range of 50-80°C. The effective diffusivities increased with the drying temperature and varied from 1.949×10^{-10} to 3.898×10^{-10} m^2/s. The temperature dependence of

diffusivity follows the Arrhenius relationship, and the activation energy for the diffusion of moisture was found to be 32.55 kJ/mol.

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References

[1] Bakshi, A. S., & Singh, R. P. (1980). Kinetics of water diffusion and starch gelatinization during rice parboiling. *Journal of Food Science*, *45*(5), 1387-1392.
[2] Crank, J. (1975). The mathematics of difiusion. *2nd end*.
[3] Dash, K. K., & Balasubramaniam, V. M. (2018). Effect of high pressure on mass transfer kinetics of granny smith apple. *Drying Technology*, *36*(13), 1631-1641.
[4] Dash, K. K., & Das, S. K. (2019a). Puffing quality and sensory evaluation of reduced sodium puffed rice. *Quality Assurance and Safety of Crops & Foods*, *11*(8), 757-768.
[5] Dash, K. K., & Das, S. K. (2019b). Optimization of fluidized bed preconditioning for microwave puffed rice using integrated artificial neural network and genetic algorithm approach. *Journal of Food Process Engineering*, *42*(6), e13158.
[6] Dash, K. K., & Das, S. K. (2020). Modeling and optimization of microwave puffing of rice using artificial neural network and genetic algorithm. *Journal of Food Process Engineering*, e13577.
[7] Dash, K. K., Chakraborty, S., & Singh, Y. R. (2020). Modeling of Microwave Vacuum Drying Kinetics of Bael (Aegle marmelos L.) Pulp by Using Artificial Neural Network. *Journal of The Institution of Engineers (India): Series A*, 1-9.
[8] Dash, K. K., Gope, S., Sethi, A., & Doloi, M. (2013). Study on thin layer drying characteristics star fruit slices. International Journal Agriculture and Food Science Technology, 4(7), 679-686.
[9] Debabandya, M., &Srinivas, R. P. (2005). A thin layer drying model of parboiled wheat. Journal of Food Engineering, 66, 513-518.
[10] Deng, L. Z., Yang, X. H., Mujumdar, A. S., Zhao, J. H., Wang, D., Zhang, Q., Wang, J., Gao, Z. J., & Xiao, H. W. (2018). Red pepper (Capsicum annuum L.) drying: effects of different drying methods on drying kinetics, physicochemical properties, antioxidant capacity, and microstructure. *Drying technology*, *36*(8), 893-907.
[11] Deng, L. Z., Yang, X. H., Mujumdar, A. S., Zhao, J. H., Wang, D., Zhang, Q., & Xiao, H. W. (2018). Red pepper (Capsicum annuum L.) drying: Effects of different drying methods on drying kinetics, physicochemical properties, antioxidant capacity, and microstructure. *Drying Technology*, *36*(8), 893-907.
[12] Doymaz, I. (2004a). Effect of pre-treatments using potassium metabisulphide and alkaline ethyl oleate on the drying kinetics of apricots. Biosystems Engineering, 89(3), 281–287.
[13] Doymaz, I. (2004b). Pretreatment effect on sun drying of mulberry fruits (Morus alba L.). Journal of Food Engineering, 65, 205–209.
[14] Doymaz, I. (2005). Drying behaviour of green beans. Journal of Food Engineering, 69(2), 161-165.
[15] Friant, N. R., Marks, B. P., & Bakker-Arkema, F. W. (2004). Drying rate of ear corn. Transactions of the ASAE, 47(5), 1605-1610.
[16] HASSAN, B. H., & HOBANI, A. I. (2000). Thin-layer drying of dates. Journal of Food Process Engineering, 23(3), 177-189.
[17] Kaleemullah, S., & Kailappan, R. (2005). Drying kinetics of red chillies in a rotary dryer. *Biosystems Engineering*, *92*(1), 15-23.
[18] Kayacan, S., Sagdic, O., & Doymaz, I. (2018). Effects of hot-air and vacuum drying on drying kinetics, bioactive compounds and color of bee pollen. *Journal of Food Measurement and Characterization*, *12*(2), 1274-1283.

[19] Khawas, P., Das, A. J., Dash, K. K., & Deka, S. C. (2014). Thin-layer drying characteristics of Kachkal banana peel (Musa ABB) of Assam, India. *International Food Research Journal*, *21*(3).
[20] Khawas, P., Dash, K. K., Das, A. J., & Deka, S. C. (2015). Drying characteristics and assessment of physicochemical and microstructural properties of dried culinary banana slices. *International Journal of Food Engineering*, *11*(5), 667-678.
[21] Khawas, P., Dash, K. K., Das, A. J., & Deka, S. C. (2016). Modeling and optimization of the process parameters in vacuum drying of culinary banana (Musa ABB) slices by application of artificial neural network and genetic algorithm. Drying Technology, 34(4), 491-503.
[22] Khawas, P., Dash, K. K., Das, A. J., & Deka, S. C. (2016). Modeling and optimization of the process parameters in vacuum drying of culinary banana (Musa ABB) slices by application of artificial neural network and genetic algorithm. *Drying Technology*, *34*(4), 491-503.
[23] Khazaei, J., & S. Daneshmandi. (2007). Modeling of thin layer drying kinetics of sesame seeds: Mathematical and neural networks modeling. *International Agrophysics*, 21, 335-348.
[24] Kingsly, A. R. P., Singh, D. B., Manikantan, M. R., & Jain, R. K. (2006).Moisture dependent physical properties of dried pomegranate seeds (Anardana). Journal of Food Engineering, 75, 492–496.
[25] Markowski, M., Białobrzewski, I., & Modrzewska, A. (2010). Kinetics of spouted-bed drying of barley: Diffusivities for sphere and ellipsoid. *Journal of Food Engineering*, *96*(3), 380-387.
[26] Nag, S., & Dash, K. K. (2016). Mathematical modeling of thin layer drying kinetics and moisture diffusivity study of elephant apple. *International Food Research Journal*, *23*(6).
[27] Ojendiran, J. O., &Raji, A. O. (2010). Thin layer drying of millet and effect of temperature on drying characteristics. International Food Research Journal, 17, 1095-1106.
[28] Prithani, R., & Dash, K. K. (2020). Mass transfer modelling in ultrasound assisted osmotic dehydration of kiwi fruit. *Innovative Food Science & Emerging Technologies*, 102407.
[29] Raj, G. B., & Dash, K. K. (2020). Microwave vacuum drying of dragon fruit slice: Artificial neural network modelling, genetic algorithm optimization, and kinetics study. *Computers and Electronics in Agriculture*, *178*, 105814.
[30] Raji, A. O., & Ojediran, J. O. (2011). Moisture sorption isotherms of two varieties of millet. *Food and bioproducts processing*, *89*(3), 178-184.
[31] Rangroo, S., &Rao, D. G. (1992). Drying of toria (*Brassica campistris*): Part 2—Drying conditions. Journal of food engineering, 17(1), 59-68.
[32] Ronoh, E. K., Kanali, C. L., Mailutha, J. T., &Shitanda, D. (2010). Thin layer drying kinetics of Amaranth grains in a natural convection solar tent dryer. *African Journal* of *Food Agriculture, Nutrition* and Development, 10(3), 2218-2233.
[33] Saxena, J., & Dash, K. K. (2015). Drying kinetics and moisture diffusivity study of ripe Jackfruit. *International Food Research Journal*, *22*(1), 414.
[34] Singh, H., &Sodhi, N. S. (2000). Dehydration kinetics of onions. Journal of Food Science and Technology, 37(5), 520–522.
[35] Sousa, A. D., Ribeiro, P. R. V., Canuto, K. M., Zocolo, G. J., Pereira, R. D. C. A., Fernandes, F. A. N., & Sousa de Brito, E. (2018). Drying kinetics and effect of air-drying temperature on chemical composition of Phyllanthus amarus and Phyllanthus niruri. Drying technology, 36(5), 609-616.
[36] Sousa, A. D., Ribeiro, P. R. V., Canuto, K. M., Zocolo, G. J., Pereira, R. D. C. A., Fernandes, F. A. N., & Sousa de Brito, E. (2018). Drying kinetics and effect of air-drying temperature on chemical composition of Phyllanthus amarus and Phyllanthus niruri. *Drying technology*, *36*(5), 609-616.
[37] Syamali, A. K., Jayaweera, H. H. E., &Ariyaratne, T. R. (2009). Thin layer drying of some Srilankan paddy varieties under low humid conditions. Proceedings of Technical Sessions, Institute of Physics, Srilanka, 25, 36-44.
[38] Toğrul, H. (2006). Suitable drying model for infrared drying of carrot. *Journal of food engineering*, *77*(3), 610-619.
[39] Togrul, I.T., &Pehlivan, D. (2002). Mathematical modeling of solar drying of apricots in thin

layers. Journal of Food Engineering, 55(3), 209–216.
[40] Tunde-Akintunde, T. Y., &Ajala, A. (2010). Air drying characteristics of chili pepper. International Journal of Food Engineering, 6(1).
[41] Wang, J., Law, C. L., Nema, P. K., Zhao, J. H., Liu, Z. L., Deng, L. Z., Gao, Z. J. & Xiao, H. W. (2018). Pulsed vacuum drying enhances drying kinetics and quality of lemon slices. *Journal of Food Engineering*, *224*, 129-138.

Adopting Sustainable Farming: Implications of Renewable Energy and ICT

Adopting Sustainable Farming: Implications of Renewable Energy and ICT

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Abstract: Contemporary sustainable farming balances higher productivity with a focus on green technological intervention. The green intervention such as renewable energy and information communication technology (ICT) though have been widely accepted by other sectors, farming community yet to yield the dividend from these two tools. In this paper, a modified technology acceptance model has been presented with a focus towards the adoptability of actual sustainable farming. Further, a success story of sustainable farming with the intervention of ICT is discussed. Finally, interdependency of renewable energy and ICT is elaborated with a focus to formulate a generalized theme towards feasibility of actual sustainability farming is presented.

Key Words: Renewable Energy, ICT, Sustainable Farming.

1. Introduction

Information and Communication Technology (ICT) and Renewable energy has played a pivotal role to accomplish holistic growth objectives of both developing and developed economy. The World Summit on the Information Society in 2003 addressed e-agriculture and featured the application of ICTs as a priority in agricultural development. ICT help to provide adequate knowledge to many farmers. It offers predictive information regarding weather, fertilizers and pest intake, as well as to bring transperancy in processes like land litigation, and market pricing. E-governace has empowered farmers of interior location to access adequate information with all convenience (Ghosh and et al., 2020). Agriculture is the foundation and backbone of the Indian economy and 68% of Indian population is chiefly dependent on agriculture for their livelihood and stake in gross domestic product (GDP) is found to be nearly 20 percent. The agricultural sector in India is lagging behind in many aspects and characterized by poor infrastructure in connectivity along with disintegrated and diversed market. The fragmented land ownership of farmers with less adoptability of technology in farming often often faces challenges in accessing reliable and timely information. ICT has enabled the reform in the traditional practices of

agriculture for augmented productivity and sustainability (Gangopadhyay et al., 2019; Karanasios and Slavova, 2019; Lindblom et al., 2017). Appropiate applications of ICT in farming sectot is expected resolve the issues of food security. Customised ICT plays crucial role in facilitating marginal farmers for optimal utilization of available limited resources. ICT enables in defining, storing, and retrieving data for dissemination in agriculture sector with the support of both public and private agencies. Thus farming community are able to access information with the help of user friendly need based information of their respective geographic location. Hence, ICT in agriculture has become an important field of research and application related to e-agriculture.ICT has great impact in agriculture sector because it provides information about business activities related to agriculture supply chain, profitability of farmers as well as value to the customers. Further it helps in retaining of existing stakeholders, as well as acquiring new dimension for financing, and investment avenues. Tools and techniques of ICT helps in accessing formulating market strategy for sourcing and delivery systems. Internet is a significant source for gathering the present information on every part of agriculture and transforming agricultural sector into modern digital agriculture.

In various rural development projects, such as rural cluster electrification and enhanced agricultural technology, information and communication technologies have been introduced to make agriculture more sustainable (Choudhury et al., 2016, Ghosh et al., 2020). Renewable energy systems are those that are not prone to degradation and use primary energy supplies. Examples of green energies include solar, wind, geothermal, and biomass. Solar energy is the light that comes right from the Sun. It is the most concentrated source of energy on Earth, including nuclear weapons. Photovoltaic cell, which transforms sunlight directly into electricity, is the fastest growing form of renewable energy, rising at 50 per cent a year. The Sun provides more than 10 000 times the electricity actually consumed by humans per year. The renewable energy was implemented in different agriculture system and successful results were achieved (Khan et al., 2018; Liu et al., 2017; Chel et al., 2011). The renewable energy can be implemented to compensate the energy shortfall in a cost-effective and environmental sustainable manner (Choudhury et al., 2018). Different cost-effective approaches have been developed by various researchers using solar power, wind power, hydroelectric power for use in various industrial sectors, technical institutions and underdeveloped rural areas (Parida and Chatterjee, 2016; Parida et al., 2016a; Parida et al., 2016b). The different energy sources, e.g. solar, wind, hydraulic, biomass, organic waste, biofuels, and combined heat and electricity, provide the electric generator with a simple, reliable and efficient solution. Conserving important non-renewable natural fuels without causing degradation to the atmosphere. Solar energy can be used in its different ways, e.g. solar photovoltaics, direct solar thermal, and green energies and wind can provide the solution to the world's energy challenges and potentially making the atmosphere safe for future generations by reducing air emissions from the use of fossil fuels.

The Technology Acceptance Model (TAM) is an information system theory for using a modern technology which simulates how users embrace and use a technology different studies on implementation of TAM user acceptance of word processors spreadsheets (Mathieson, 1991), e-mail (Szajna, 1996), voice mail (Straub, 1995) , and telemedicine technology (Hu, 1999). The Technology Acceptance Model has been tested empirically and applied in multiple applications (Mathieson, 1991; Taylor and Todd, 1995; Venkatesh, 2000; Moon and Kim, 2001; Liu et al., 2010; Bagozzi, 2007; Davis 1989; Lee et.al., 2003; Venkatesh and Davis, 1996; Venkatesh et.al., 2003). The overall objective of the research was to analyze the linkage of the Renewable Energy, information and communication technology to agriculture sector for sustainable farming. The specific objectives of the research were to implement Renewable Energy and Information and Communication Technology (ICT) for Adopting Sustainable Farming and evaluate the efficiency of the process. The proposed paper has also outlined the implication of Technical Acceptance Model (TAM) to achieve the same.

2. Research model and hypothesis

2.1. Application of information and communication technologies for sustainable farming

Poor farmers lack credit for the purchase of farm inputs such as seeds, fertilizers, crop protectants. Smaller or more distant farmers always have fewer trading opportunities and they have to rely on a few traders with less attractive credit conditions, or may not at all have access to credit from the commodity market. ICT is one of these alternatives, which has recently unlocked tremendous capacity to directly strengthen agriculture in developed countries. ICT has found a foothold in the booming mobile, telecom and Internet markets, including in vulnerable smallholder farms and their operations. Computer-based technologies and networking mechanisms such as social media, data archives of information (online or offline), digital imagery and film, and cell phones are all included in ICTs.

It enables accessing requisite information embedded with Just-in-Time (JIT) for the beneficiaries located at distant geographic location at an affordable cost. This also guarantee gender equality and involve women in the course of decision making. ICTs have the option of receiving immediate and accurate reports of the software, operation, applied technology or information. It helps to increase efficiency and quick accomplishment of work. The mechanism will reinforce the seed industry, such as timely and updated reports on seed-related issues such as the introduction of new crops, false seeds and seed price information, etc. Sustainable growth of rural & agricultural areas is also supported by ICT. This also helps to empower rural netitizens with the conservation of environment by avoiding unwanted exploration through implementation of appropriate technology, and productive strategies for development, markets, banking and financial services. ICT is concerned with recording, extracting and distributing digital data. ICT makes the system more competitive, efficient and attentive to meet the demands.

2.2. Application of Technology Acceptance Model for sustainable farming

The technology acceptance model (TAM) was implemented to predict the acceptability of a mechanism and to define the improvements that may be added to the system. As per TAM, perceived usefulness (PU) and perceived ease of use (PEOU) are decisive factors regarding the acceptability of any information system. In addition to this the technology acceptance model suggests that the use of an information system is determined by the behavioral intention.

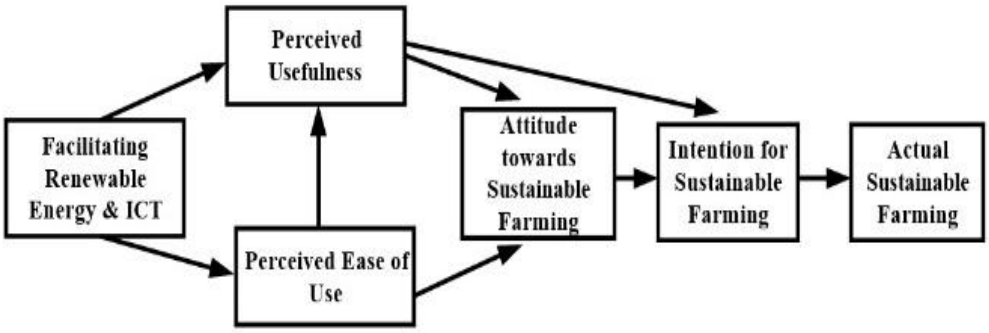

Figure-1: Proposed technology acceptance model for sustainable farming

For sustainable agriculture the behavioral intention is dependent on 3 factors such as attitude towards sustainable farming (AS), intention for sustainable farming (IS), and confidence for implementation of

sustainable farming (CIS). The technology acceptance model for the sustainable agriculture is shown in Fig1. PU denotes the degree of the conviction of a person that a certain scheme is being used can boost its efficiency. Whereas, PEOU indicates affinity of an individual belief system for easy usage of a specific creative information system. AS is defined as the degree to which a farmer implements ICT and renewable energy for sustainable farming. The intention of sustainable farming (IS) implies the intent of individual users and is characterized as a type of external psycho-motor response quantified by the actual course of action of individual users.

In this study the relationship between ICT and renewable energy and sustainable farming was established. ICT and renewable energy is meant for the implementation for farming system by the farmers. Although there are various real and observable benefit steps a simple approach has been created to quantify and calculate the implements of ICT and renewable energy for sustainable farming. In the selection of the necessary details for the design, a method of survey was implemented. A standardized questionnaire consisting of a series of questions was taken as a testing tool. The methodology of questionnaire surveying was used in order to collect primary results. A major portion of the questionnaire consisted of semi-closed questions such that each respondent could select from the alternatives presented and also share their opinion. The TAM questionnaires were implementing renewable energy and ICT, perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation. The participants were asked to responds the questions asked above using the 5 points (1-5) Scale. The five point scale was designated as1 as lowest point with denoting ‘strongly disagree’ and 5 as ‘strongly agree’ and subsequently other interval number denotes all other interval values. Twenty elderly people (over 51 years of age), twenty middle-aged people (between 31 and 50 years of age) and twenty younger adults (between 18 and 30 years of age) from the local population were chosen for the study. Every member of the group should be able to use smartphones and computers. An introductory overview on ICT and green energy was presented to all participants. In order to test the model parameters, they were expected to finish a survey and attempt all the given questionnaire and the score had to be provided on the five-point scale.

3. Results and Discussions

In agriculture system ICT and Renewable energy are used in weather forecasting, taking expert opinion, and for farming techniques by illustrative video. Renewable energy was implemented for generating and storage of electricity which further can be implemented for electricity based water pump and storage of farm output. The Indian farmers are lesser interested for implementation of ICT and renewable energy in agriculture due to their low level of education, and higher initial cost of investment for implementing the technology. The farmers often risk introducing the technique because they are not sure about the yield. ICT is mainly dependent on electricity. Privatized mega-power plant can't afford less efficient rural electrification, so green energy can help marginal farmers make it sustainable by partnership at village level.

3.1. Descriptive statistic for parameters of sustainable farming

The descriptive statistics pertaining to the different factors of sustainable agriculture are shown in Table 1. The mean score of the variables implementing renewable energy and ICT (IRE-ICT), perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation were 3.43, 3.70, 3.31, 3.60, 3.76, and 4.06 respectively. The score of each variables was higher than average which indicated that the strongly agree with each parameter of sustainable agriculture.

Table 1 Descriptive statistics of the variables for implementation of sustainable agriculture				
Variable	*Minimum*	*Maximum*	*Mean*	*SD*
Implementing renewable energy & ICT	*1.00*	*5.00*	*3.43*	*1.43*
Perceived usefulness	*1.00*	*5.00*	*3.70*	*1.29*
Perceived ease of use	*1.00*	*5.00*	*3.30*	*1.44*
Attitude towards sustainable farming	*1.00*	*5.00*	*3.60*	*1.40*
Intention for sustainable farming	*1.00*	*5.00*	*3.77*	*1.22*
Confidence for implementation	*1.00*	*5.00*	*4.07*	*1.11*

3.2. Correlation between variables of sustainable farming

The correlation coefficients among the various variables are summarized in Table (2). According to the findings obtained there is a positive and significant relationship between the variables implementing renewable energy and ICT, perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation. It was observed that implementing renewable energy and ICT was strongly correlated with attitude towards sustainable farming ($p < 0.01$, $r = 0.604$) and the correlation was found to be significant.

Table 2 Correlation coefficients between the Technology Acceptance Model parameters						
Variables	*IRE-ICT*	*PU*	*PEOU*	*AS*	*IS*	*CIS*
IRE-ICT	*1*					
PU	*0.558***	*1*				
PEOU	*0.537***	*0.55***	*1*			
AS	*0.604***	*0.426**	*0.572***	*1*		
IS	*0.415**	*0.522***	*0.354*	*0.566***	*1*	
CIS	*0.393**	*0.135*	*0.202*	*0.172*	*0.113*	*1*

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficients of implementing renewable energy and ICT with perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming and confidence for implementation with implementing renewable energy and ICT were 0.558, 0.536, 0.604, 0.414, and 0.393 respectively. Therefore, the use renewable energy such as solar, hydro-power or wind-farms in sustainable agriculture is highly beneficial for the farmers. Farmers can use renewable based rural electrification technology for electrical fencing of agriculture land. Irrigation for optimal watering by electric pumps. Post harvest activity can also be achieved by the usage of electric dryer. For this purpose, marginal farmers can use solar panel based irrigation for distantly located farmland. At the same time established farmers can rely upon geothermal heat pumps. The correlation between perceived usefulness and perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation were evaluated. Based on the results obtained there was positive and significant relationships between perceived usefulness and perceived ease of use ($p < 0.01$, $r = 0.550$) and also relationships between perceived usefulness and intention for sustainable farming was found to be highly significant ($p < 0.01$, $r = 0.522$). The correlation between confidence for implementation was found to be significant for implementing renewable energy & ICT whereas the correlation between confidence for implementation and perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming was found to be insignificant ($p > 0.05$). The findings of correlation experiments have shown that the model variables are related to each other.

4. Conclusion

This paper analyzed the use of the TAM as deterministic for the acceptance of ICT and renewable energy in sustainable farming. The study has a novel addition of implementation of renewable technologies leading to sustainable farming. This study was conducted to classify and correlate the parameters implementing renewable energy and ICT, perceived usefulness, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation towards sustainable agriculture technologies. There is a significant positive relationship observed between the variables implementing green energy and ICT, perceived utility, perceived ease of use, attitude towards sustainable farming, intention for sustainable farming, and confidence for implementation, according to the findings obtained. ICT would enhance interchange of their experience with an interactive ICT based systems for both tangible and intangible causes. Farmers with minimal access to resources, energy and technology can access information via computer-based apps and networking platforms such as social media, digital database archives, and digital imagery and recording, as well as mobile phones. Farmers with minimal access to resources, energy and technology can access information. The analysis offers valuable perspectives for farmers and decision makers of implementing ICT and renewable energy for sustainable agriculture.

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References

[1] A. Parida, D. Chatterjee, (2016) A solar PV augmented hybrid scheme for enhanced wind power generation through improved control strategy for grid connected doubly fed induction generator, Cogent Engineering, 3: 1147337. doi.org/10.1080/23311916.2016.1147337
[2] A. Parida, S. Choudhury, S. Chatterjee, D. Chatterjee, (2016a) A cost effective trade-off based renewable power augmented energy efficient load model for manufacturing industries for demand side management", Cogent Engineering, 3: 1239299. doi.org/10.1080/23311916.2016.1239299
[3] A. Parida, S. Choudhury, S. Chatterjee, D. Chatterjee, (2016b) A rule based electrical energy distribution model for energy efficiency in technical institutions: A case study, Energy and Buildings, 126, 508-516. doi.org/10.1016/j.enbuild.2016.05.069
[4] Bagozzi, R. P. (2007). The legacy of the technology acceptance model and a proposal for a paradigm shift. Journal of the association for information systems, 8(4), 3.
[5] Chel, A., & Kaushik, G. (2011). Renewable energy for sustainable agriculture. Agronomy for Sustainable Development, 31(1), 91-118.
[6] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, 319-340.
[7] Gangopadhyay, P. K., Khatri-Chhetri, A., Shirsath, P. B., & Aggarwal, P. K. (2019). Spatial targeting of ICT-based weather and agro-advisory services for climate risk management in agriculture. Climatic change, 154(1-2), 241-256.
[8] Hu, P. J., Chau, P. Y., Sheng, O. R. L., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. Journal of management information systems, 16(2), 91-112.
[9] Karanasios, S., & Slavova, M. (2019). How do development actors do "ICT for development"?

A strategy-as-practice perspective on emerging practices in Ghanaian agriculture. Information Systems Journal, 29(4), 888-913.
[10] Khan, M. T. I., Ali, Q., & Ashfaq, M. (2018). The nexus between greenhouse gas emission, electricity production, renewable energy and agriculture in Pakistan. Renewable Energy, 118, 437-451.
[11] Lee, Y., Kozar, K. A., & Larsen, K. R. (2003). The technology acceptance model: Past, present, and future. Communications of the Association for information systems, 12(1), 50.
[12] Lindblom, J., Lundström, C., Ljung, M., & Jonsson, A. (2017). Promoting sustainable intensification in precision agriculture: review of decision support systems development and strategies. Precision Agriculture, 18(3), 309-331.
[13] Liu, I. F., Chen, M. C., Sun, Y. S., Wible, D., & Kuo, C. H. (2010). Extending the TAM model to explore the factors that affect Intention to Use an Online Learning Community. Computers & education, 54(2), 600-610.
[14] Liu, X., Zhang, S., & Bae, J. (2017). The nexus of renewable energy-agriculture-environment in BRICS. Applied energy, 204, 489-496.
[15] Mathieson, K. (1991). Predicting user intentions: comparing the technology acceptance model with the theory of planned behavior. Information systems research, 2(3), 173-191.
[16] Moon, J. W., & Kim, Y. G. (2001). Extending the TAM for a World-Wide-Web context. Information & management, 38(4), 217-230.
[17] S. Choudhury, A. K. Patra, A. Parida, S. Chatterjee, (2018) Renewable energy capacity estimation for Indian energy sector using energy demand forecasting through Fuzzy Time Series, Advances in Smart Grid and Renewable Energy, Springer, 551-558. doi.org/10.1007/978-981-10-4286-7_54
[18] S. Choudhury, A. Parida, R. M. Pant, S. Chatterjee, (2016) GIS augmented computational intelligence technique for rural cluster electrification through prioritized site selection of micro-hydro power generation system, Renewable Energy, 142, 487-496. https://doi.org/10.1016/j.renene.2019.04.125
[19] S. K. Ghosh, A. K. Das and S. Choudhury, (2020) ICT Interventions in Rural Development Schemes: A Case of Rupshi Development Block, Assam, 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2020, pp. 349-354, doi: 10.1109/ICRITO48877.2020.9197987.
[20] Straub, D., Limayem, M., & Karahanna-Evaristo, E. (1995). Measuring system usage: Implications for IS theory testing. Management science, 41(8), 1328-1342.
[21] Szajna, B. (1996). Empirical evaluation of the revised technology acceptance model. Management science, 42(1), 85-92.
[22] Taylor, S., & Todd, P. (1995). Decomposition and crossover effects in the theory of planned behavior: A study of consumer adoption intentions. International journal of research in marketing, 12(2), 137-155.
[23] Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. Information systems research, 11(4), 342-365.
[24] Venkatesh, V., & Davis, F. D. (1996). A model of the antecedents of perceived ease of use: Development and test. Decision sciences, 27(3), 451-481.
[25] Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS quarterly, 425-478.

Significance of Renewable Energy for Empowering Cooperative-Farming Sector in Majuli Island of India

Significance of Renewable Energy for Empowering Cooperative-Farming Sector in Majuli Island of India

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Abstract: Agriculture is the backbone of the Indian economy and plays a vital role in the overall development of the country. Many studies and practices have proved the importance and benefits of electricity in agriculture throughout the world. However, the fossil fuel-based conventional energy supply to agriculture is always associated with environmental issues. In an attempt to study the significance of renewable energy in the cooperative farming sector particularly in the biodiversity regions, Majuli Island of Assam, India has been selected for the case study. Even though the major income source in the said locality is agricultural farming, they are deprived of getting the optimum benefit from this indigenous income source due to lack of technological intervention. Technological intervention in this sector in the biodiversity region is not imaginable without exploring the feasible intervention of renewable energy at an affordable energy cost. Therefore, in this paper, the significance of renewable energy in agriculture considering the environmental issues has been highlighted in general and in cooperative farming in particular.

Key Words: Renewable Energy, Cooperative Farming, Environmental Issues, Sustainable Livelihood.

1. Introduction

The World's biggest waterway island, Majuli, situated in the Brahmaputra stream of Assam state, is recently declared as first island district of India [1-3]. It covers a zone of 352 sq. km and a populace of around 1, 67, 304 (approx.) [2], [4]. The beautiful excellence and uniqueness of the Island make it a vacationer location for people groups, all around the globe [4]. Both abroad and homegrown sightseers visit here on a regular stretch and along these lines makes a road for the job of the Island [4-5]. Aside from Tourism, small scale cottage industries are also providing employment opportunities in this area[2]. From the primer examination by the creators, it has been discovered that the essential type of revenue here is principally from horticulture, around 75% of the all out populace totally relies on farming for their vocation. [1-2], [4].

1.1 Cooperative-Farming

"Cooperative" in different sectors is coexisting from the last few decades, farming, is one among them. However, cooperative-farming is a novel concept conceptualized appropriately in various studies [4]. Cooperative farming is a type of farming system where each farmer remains as the proprietor of their land but the farming activities are carried out collectively by a group of farmers through cooperative activities and technological intervention [4], [6], [6]. The profit and loss from these farms are distributed among the farmers based on the ratio of the land they have own [4]. With the help of certain agencies formed by the farmers and for the farmers, individual farmers performed their farming activities jointly in their holding [4], [6-8]. These agencies also help in purchasing and sending of farm inputs and outputs. The basic idea behind agricultural cooperative is to pool the resources for getting the benefit of 'Teamwork' and thereby reducing risk rate. Cooperative farming in different forms has already tried and still practicing in different countries such as the UK, Germany, France, etc. for the last few decades [8-11].

1.2 Cooperative Farming and Renewable Energy

Many studies have proved that the highest efficiency in farming can be achieved only by the means of electrical energy and hence technological intervention. Technological intervention in the area of agriculture will increase the competence of certain farming activities. Usually, farming activities are carried out by manual labor and with conventional tools such as sickle, ploughing, etc. but renewable energy-based mechanized farming will reduce the manual work and automats the farming activities thereby saving time and energy. Renewable energy can play a major role in agriculture and particularly in cooperative farming for sustainable growth. Moreover, the intervention of renewable energy in farming will not only help in rural development missions but also creates a sustainable environment for the entire world in terms of reduced carbon-cost [12]. Based on the case-study conducted at the *"Borgayan"* village of Majuli district, the following points are the contributions of this manuscript.

1. The significance of the renewable sources of energy in the corporative farming sector for the said location and its feasibility study has been discussed systematically.
2. The analysis of the existing agricultural practices and socio-economic scenario of the proposed case-study location has been detailed
3. The benefits of cooperative farming, the intervention of technology, and the introduction of renewable energy in the cooperative farming structure have been discussed.

2. Literature Review

Some of the similar reviews done by various authors in their respective journals are: Bardi, Toufic, and Lavacchi, (2013), in their study "Turning electricity into food: the role of renewable energy in the future of agriculture, says that encouraging the use of electric power in the farm is a worthy effort, even though it is not possible to replace renewable energy with fossil fuel simply, leaving everything unchanged, but it is possible only utilizing more efficient use of energy and mineral resources, as well as an approach in a more respectable way to preserve soil and local resources. R Athira, and et al(2019), in their research, "Proposed Cooperative Farming as a Catalyst to Livelihood Augmentation for the Marginal Farmers of Majuli Island, said that the cooperative system will not only increase the standard of living but also increases the feeling of friendship, cooperation and thereby achieves synergy in the agricultural sector. Keely AR(2016) in his study, "Renewable Energy in Pacific Small Island Developing States: the

role of International Aid and the Enabling Environment from Donor's Perspective, studies that, High targets supported by well-structured action plans and effective regulator body is responsible for RE and also financial aspects of utilities hold a higher importance than technological aspects of utilities. Dhunny, Allam, Lobin, and Lollchund (2019) in their research," Sustainable renewable energy planning and wind farming optimization from a biodiversity perspective, proves that, in an economic analysis performed for understanding energy generation of scenarios in respect of the selected site, reveals a positive result inefficiency of the model and its potential applicability to other sites, who are looking for sustainable energy planning. Elaine Forde, (2017), in his study, "The Ethics of energy provisioning: Living off-grid in rural Wales", argues that living off-grid comprises of materially engaged ethics of usage of energy, emerges from and situated in everyday realities of off-grid energy provisioning. R, Borlase Matthews (1922), in his topic," Electro Framing or the Application of electricity to agriculture" in his experimental study suggested that the highest efficiency in farming can be only achieved through electricity. Chetan Dwarkani, (2015) in their study, "Smart Farming System Using Sensor for Agricultural Task Automation", developed a user-friendly smart farming system and suggest that it liberates agricultural productivity and mode of production can be changed. Fabio Riva and Emanuela Colombo (2020). In their research, scientific reports only show controversial results regarding the impact of electrification programs and most of the time provide attributable to inappropriate planning of off-grid capacities of the system. Bikash Das (2017) in his study on, "An overview of the economic condition of Majuli, the largest inhabited river island of the world", says that most people of River Island depend upon agriculture, but, the traditional agricultural system o Majuli results in low productivity." V.J.P.D. Martinho (2020), in his study," Relationship between agriculture energy and farming indicators", says that reviews concerning agriculture energy and pollution highlight that there is a relevant relationship between energy consumption, economic development, and environmental impacts. Kurunathilake H (2016), in this research," Renewable energy integration into community energy system: a case study of new urban residential development", reveals that the Renewable energy system depends upon local situations energy availability, etc.

3. Research Methodology Area

3.1. Case Study Area

The research was carried out in a village named Borgayan Village, situated in Majuli District, Assam. The literacy rate of the village, compared to Assam, is very low and no modernization has happened yet. People groups here totally relies on horticulture for their occupation just as for their every day needs. Rice is the principle cultivation here. Aside from this, many are additionally into kitchen cultivating. [4].

3.2. Data Collection

The research was done using both primary and secondary data. Primary data was collected using survey method, a field visit was done and directly interacted with the farmers at work, thereby first-hand data were used for the study. Other primary sources includes interview method, random sampling, personal observation method, etc. The Secondary data collection was made based on different sources such as census, various related journals, other publications, articles, e-journals, books, recent reports, etc.

An isolated island, no connected examination has been done in Majuli, till this date. Accordingly, the "Theory Building" idea has been utilized for proposing the model, of this paper. Theory building, is a broadly utilized idea in research territories, as it gives an examination structure to the investigation, additionally a proficient field improvement should be possible utilizing this idea and also it helps in further applicability for solving the problems and issues related to the practical real world. Theory, however a dreary artistic expression, practical, without theory, can be hazardous and dull. In explanatory

reasonable examination, a subcategory of "theory building" idea, adds new bits of knowledge into conventional issues through logical relationship building. So in this paper, we utilized the "theory Building" concept, along with primary and secondary data, for the study [13].

4. The Present Agricultural Scenario of Majuli Island

Majuli Island is situated in the Brahmaputra River of Assam. It was one of those three subdivisions of Jorhat District, but recently in September 2016, the river island Majuli is declared as one of the districts of Assam [1]. In spite of the fact that a confined island, the picturesque excellence improved with greenery makes it a traveler center point for people groups from various pieces of the world. Farming is the essential kind of revenue here, around 75% of the absolute populace relies on horticulture for their occupation. The climatic condition and soil of Majuli are very appropriate for development. Primary cultivating here is rice, mustard, vegetables, and so on from the complete region of Majuli around 41.43 percent of the zone is utilized for development. Ranchers here are generally negligible ranchers, having little landholdings of 0.95 hectares [4]. Modernly, Majuli is a little in backward spot in the entire of Assam. Absence of modernization, innovative headway, absence of legitimate transportation facility, geological disconnection, and so forth can be the explanation behind this. Despite the fact that, couple of cottage and small scale industries are existing in Majuli, for example, ceramics industry, boat making industry, handloom, stick bamboo, and so on [2]. Aside from this sericulture is additionally a significant agro-based industry of Majuli. Majuli is additionally famous for its fishing area, around 10%-20% of clans here, fundamentally ST and SC, are occupied with fishing [4].

4.1. Current Scenario of Borgayan Village

The town we chose for the research was Borgayan. As per statistics 2011, the all out populace of the town is 1320. Rice and mustard are the fundamental development here in the town, around 90% of the populace are into horticulture. Three primary sorts of rice crops are developed here. The yield development graph is given in Table 1. Ahu-Dhan and Mustard are the fundamental harvests here. This town is additionally well known for the black gram and curd [2]. Peoples here additionally insignificantly do kitchen cultivating, just to meet their every day needs. Apart from this, the other sources of revenue are from livestock, fish ponds, and so forth some are also workings labors at nearby small-scale industries.

Table-1: Crop Cultivation of Majuli

Crops	*Harvesting*
Ahu-Dhan (rice)	*Jan-July*
Baw (rice)	*April-Dec*
Mustard	*Sep-March*
Chana Dal	*Nov-May*

It is found that farming here is done using the traditional system of agriculture. Due to a lack of modernization and technology availability, peoples here get a minimum profit. For irrigation peoples here depends upon “rain”. Only 5% of farmers use pumps for irrigating their land and that too a diesel one. Based on land availability, some also do multi-cropping. Mustard is the only crop, used for trade purposes. Harvested mustards are collected by brokers directly from the farm and sell it to the mill, thereby brokers are more benefited and farmers get less benefit. For rice, farmers here, after harvesting, store the grains in a “bharl”, a small room made up of bamboo and dried grains. Based on the need, these grains are taken to the mill and processed into rice, the rice husk is used as cattle feed and rice for their daily needs. Here, a conventional method of farming system is used. As every farmer, having land, does their farming on that particular lad itself. Here, the profit and loss is beard by the individual farmer himself. As a being an isolated island, Majuli is facing issues like soil erosion, flood, etc, when such calamities affect farming the farmers have to face the entire loss, and sometimes the loss can be too high

for a marginal farmer to bear [1]. The other issue of this system is that the small farmlands divided with boundaries create a problem for proper irrigation as well as for proper drainage related issue. Since there was no other option available, farmers were facing the entire struggles.

5. Renewable Energy and Cooperative Farming Correlation

5.1. "Cooperative" in detail

Many studies have proved that "cooperative farming" or "collective farming" can resolve many issues of individual farming [14-15]. The basic concept of these farming is to pool together the land and resources. In this system, each farmer will remain as the owner of their respective land but farming will be carried out jointly. Here the profit and loss incurred from agriculture will be divided based on the ratio of land, the farmer holds [6]. Based on the number of days/ hour, they work, wages can be decided and distributed accordingly. In this system, the land earlier used for dividing boundaries can be used for cultivation, hence, wastage can be reduced. As working together, the feeling of brotherhood and spirit of synergy can be achieved [4], [6], [8]. It is found that in many developed countries, a large proportion of farmers rely on a cooperative system of agriculture to govern both forward and backward market transactions [6], [8]. Many producers are joining the force in agriculture cooperative by becoming its member and using the services, the collective organization provides. Existing cooperative farming can be divided into two: a) agriculture production cooperative, which helps in land pooling and using resources jointly b) agricultural service cooperative, which provides basic services required for farming such as warehousing, storing, etc. mainly the agricultural inputs are purchased from the market, at a reasonable price, but when the market fails to do so, cooperatives form [4].

5.2. Significance of Renewable Energy Based Electricity

In view of numerous ongoing examinations it is discovered that most extreme productivity in agriculture can be arrived at simply by the utilization of the electrical technique [16]. The utilization of power in cultivating is numerous, for example, in the poultry area, electric light, and etc, the details are shown in Table-2.

Table 2: Details of usage of Electricity in Farm

Use in Farm Building	• *Electric light for dairy, yards, milking, chaff, food preparation, dust extractor* • *Dairy- milk separation, cooler* • *Poultry- increasing egg production, egg tester, etc.*
Use in Farming Land	• *Manure distribution by electric machines* • *Plowing* • *Irrigation purpose* • *Electric engines for farmland works*
Treatment of Crops	• *Preparation of seed- bathing of seed, seed drying, etc.* • *Gathering groups- hay drying, pulp extraction from fruits, etc.*

Apart from this, a lot of works that ought to be substantial by electric power, is currently being done by manual labor [17]. However, these farmers are not aware that electricity can assist them to a great extent until someone shows them the possibilities. Currently, they are forced to work with all their effort with disregard of time. Though electric light is avoided or considered to be less important, bringing these

electric light will allow the safety and convenience of their work apart from agriculture, livestock farming can also be done using electricity [16]. Sufficient milk from cooperative farming can be stored and used for other purposes in the food processing section can be done easily done using cooler facilities through electro farming [16],[18]. An experiment done on a foreign farm shows that certain electric light treatment can be used for egg-laying and earlier maturity of livestock [18]. In India, around 70% of the population is into agriculture, contribution to GDP is 8%. The main reason behind this deprived performance is the lack of automation in the agriculture sector. Because of the absence of appropriate advancement, farmers are not able to update themselves. They are not even able to get to know about the benefits and programs from the government. With the help of electricity, many issues can be solved. Digitalization is also an important element along with electricity [17], [19-20]. The sector agriculture plays an important role in reducing poverty, providing food, earning foreign exchange, etc. but the main input needed to sustain the agro sector and its growth is irrigation which requires access to electricity at farms [20]. Studies have proved that electrification to the farm can increase yields and consequently income from the farm through adopting electric pumps for irrigation and also other needy applications [17], [20]. This is a labor-saving technology for farmers and also reduces the expenditure on hired labor and time consumption. Adoption of electricity can also benefit farmers from the issue of getting access to information related to getting the best practice of farming through an internet connection [4], [21].

5.3. Adopting Renewable source of Energy

In many different parts of the world, electricity is being used in the agriculture sector and are getting maximum benefit too [22]. But it is found that modern technology-based agro farming is depending upon energy supply obtained from fossil fuels or we can say the conventional source of electricity. Fossil hydrocarbon is a limited source to rely on completely and also its harmful effect on the environment creating an urgent need for reducing their use [19], [23]. By this agriculture, which meant to be the highest livelihood provider, ultimately resulting in one of the major emitters of greenhouse gas [24]. This question is about the sustainability of the environment. The continued use of fossil fuel may lead to a slowdown of production in near future causing serious issues to the agricultural sector [19], [25-26]. Many researchers on their different studies have proved that a renewable source of energy is the best to rely on to avoid a negative impact on the environment created by the conventional source of energy supply. So, it is important to resolve this issue, so that we can aim towards the conservation of precious resources such as the fertility of soil and water [26-27]. Renewable energy provides a wide variety of energy production in different forms, at different cost with different efficiencies, which reduces the dependency on the conventional source of energy and ensures long term energy security for the country as well [9]. RE plays a vital role in achieving primary and secondary energy supply goals such as improved diversity, energy supply security, reducing local pollutants, etc. studies have observed that there are ample amount of opportunities available with favorable geology and geographical conditions with a huge customer base and widening gap between demand and supply. Sustainable renewable energy can be of vital link for the development of the nation [28-31].

5.4. Feasibility Study on Solar PV based Renewable Energy in the Case-Study Site

The Majuli biodiversity region is situated in the global positioning of 27.0016° N, 94.2243° E. The average solar radiation *(kWh/m^2/day)* data has been collected for the year 2019 with a sample size of 7 samples/day basis using the Solar Radiation (Silicon Pyrometer) Smart Sensor - S-LIB-M003. The collected data has been shown in Fig.1.

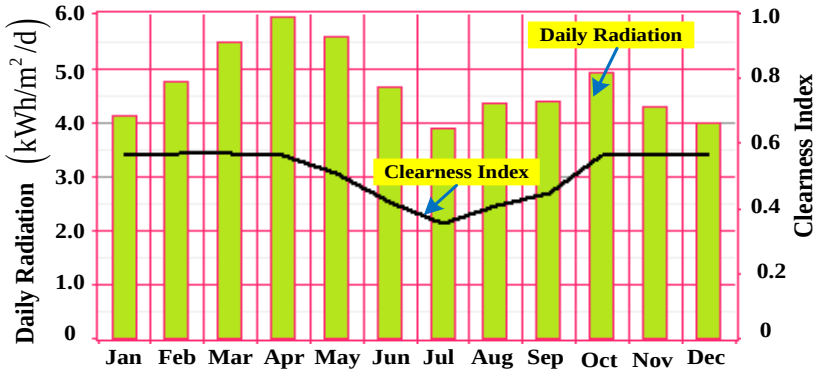

Figure-1: Average solar radiation in a year at 27.0016^{0}N, 94.2243^{0}E

It has been observed that the average solar radiation at the test site is well above the standard 0.2 (kWh/m^2/day). This is the minimum radiation level above which it is suitable for solar PV power generation site economically [32-35]. Therefore, the site is suitable for solar PV based on renewable power generation technologies. Based on a proposed 5kW solar power plant, the cost analysis has been performed in an attempt to compute the cost of energy as shown in Table-3. The estimated cost is found to be $0.1756/- which is significantly less than the present cost of energy from conventional sources at the same location.

Table-3: Cost of energy with proposed 5kW solar PV power plant

Cost Factors	*Value*
Initial Capital Investment ($)	*6600/-*
Cost of Energy ($/kWh)	*0.1756/-*
Net Present Cost ($)	*1220/-*
Operating Cost ($/year)	*675/-*

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6. Proposed Electro Based Cooperative Farming Model

Based on certain studies we designed a model, a model based on electricity and technology. The main idea of this proposed model is to lessen human labor and getting a clearer idea of responsibilities and thereby obtaining a productive environment through the activities of agriculture using a cooperative farming system based on electricity and technological advancement for the betterment of livelihood.

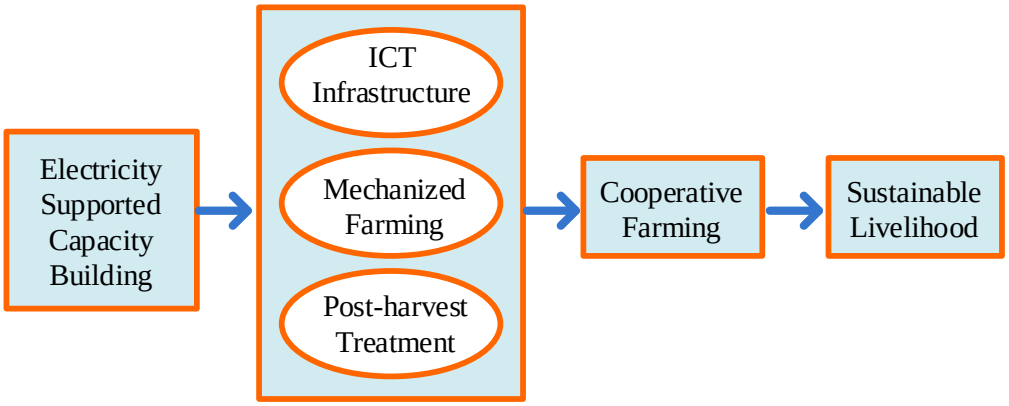

Figure-2: Proposed electro based cooperative farming model

- ***Electricity influenced Capacity Building***

Now, we all know that modernization is the basic concept behind this model. Smartly achieving maximum benefit is the concept here. To reduce those manpower labor work and optimal utilization of time can only be achieved using electricity. As it plays a very important role in all of this. Each part of the model, need electricity. We cannot deny the fact that nothing in this cooperate model can be performed without the use of electricity. We need electricity in farm machinery, food processing, use of information and technology, to get an update about all the marketing and financial stuff. The main purpose of this electricity influenced capacity building is to support the other elements of the cooperative section, through electricity, to make the working more productive in less time and also in a smart way.

a) ICT Infrastructure

This section will carry out activities related to technology and information. New farming techniques, ideas, updated information regarding the outside world, the subsidy is given by the government, and other initiatives by the government can only be acquired using this unit. Since Majuli is an isolated island, the village in which the study was carried out, found that peoples there are completely unaware of the subsidy and benefits providing by the government. The main motive behind the introduction of this unit is to build a platform for communication with the outer world using information communication technology and being updated with the technological world

b) Mechanized Farming

This unit will be dealing with the mechanical part. The usage of various farm machinery such as tractors, irrigators, other farm machines used for plowing, harvesting, etc. can be done here. This area will give training to peoples and will be carrying out the mechanical parts. Not only in the farming area but also food processing section. Plants, machinery, etc. will be dealt with by this unit. Under this unit, an idea will be given regarding the farming pattern, current technology, farming culture related to climatic condition, soil pattern, etc. this stuff can be very familiar to peoples who are into farming there. But the newcomers or new generations who are new to this field will not have many ideas about the land and soil. The main purpose of this unit is to give needy ideas and knowledge to upcoming people about the fertilizer, its amount to be used, its impact on soil, making them aware how to deal with manure, identification of soil fertility, cropping pattern, smart irrigation of land using modern technologies, etc.

c) Post-Harvest Treatment

The agricultural output, need to be processed in mills and products like grains which are usually taken to mill to separate the husk, can be done here in a cooperative unit. Apart from this, the excess products that can be processed into new brands for trade purposes can also be done here. Hence, all the activities related to food, food processing, agricultural output, etc. can be carried out in this "post-harvest treatment" unit. The processed food which needs to be sent for trade purpose can be done by this section. Also, the decisions regarding linkage with the outside market such as purchasing agricultural inputs like seed, fertilizers, etc. can be made by this unit. The overall marketing, advertising, selling related kinds of stuff can be performed by this group. Therefore, these three renewable energy-based sections

will ultimately contribute to cooperative farming. Where peoples will be carrying out their farming activities in a cooperative way as discussed earlier in this article, and finally contributing to sustainable livelihood development. As studies have declared that sustainable development is a paramount issue that requires urgent action and changes from the side of government and society as a whole [36]. In this model, we focused on renewable sources of energy which will switch from the demand need for fossil fuel in a farming area and thereby enjoying a sustainable cooperative development of the area.

7. Conclusion

Hence, the basic need for electricity and its importance in the agricultural sector is discussed. As many actives, of machine nature, are currently being done manually. This leads to high cost, time-consuming and resulting in low productivity, therefore, the paper focus on achieving a cooperative sustainable farming system by replacing green energy sources with conventional one. An electro based cooperative model was developed and proposed in the paper, the technical based cooperative model, if implement properly can result in various benefits such as providing a platform for communication with the outer world, systematic and structured working pattern where each one gets a clear idea about the work, increased production, economic development of farmers, market linkage, optimal utilization of land, organized source of employment, bulk surplus, being a cooperative, high valued machinery can be purchased, etc. the benefits are enormous. With this cooperative model, since people working jointly will bring the synergy and love of brotherhood can also be achieved. If implemented properly can also provide employment opportunities within the village as well.

Acknowledgments

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References

[1] Goswami, R., et al., (2013) Arsenic in the groundwater of Majuli- The largest river Island of the Brahmaputra: Magnitude of occurrence and human exposure, *Journal of Hydrology*, vol. 518, pp. 354-362. http://dx.doi.org/10.1016/j.jhydrol.2013.09.022

[2] Bikash Dash, (207) An overview of the economic condition of Majuli, the largest inhabitant river Island of the world, *International Journal of Interdisciplinary and Multidisciplinary Studies (IJIMS)*, vol 4, pp. 91-96.

[3] Kmar, M Goswami, R., Awasthi, N., Das, R., (2019) Provenance and fate of trace and rare earth elements in the sediment-aquifers system of Majuli River Island, India, *Chemosphere,* vol. 237. doi:http://doi.org/10.1016/j.chemosphere.2019.124477

[4] Athira R, A Parida, S Choudhury, (2019) Proposed Cooperative Farming as a catalyst to livelihood augmentation for Marginal farmers in Majuli Island, *2nd International Conference,* ISMS 2019.

[5] A. Borborah A., M.G. Borborah, S. Choudhury (2016) Prospects of Ecotourism in Majuli. In: Purkayastha J. (eds) Bio prospecting of Indigenous Bio resources of North-East India. *Springer, Singapore*. https://doi.org/10.1007/978-981-10-0620-3_20

[6] Vladimir Milovanovic, Lubos Smukta, (2018) Cooperative rice farming within rural Bangladesh, *Journal of Cooperative Organization and Management*, vol. 6, pp. 11-19. https://doi.org/10.1016/j.jcom.2018.03.002

[7] Gong T (Charles), Battese GE, VIllano RA, (2019) Family Farms Plus Cooperatives in China:

Technical Efficiency in Crop Production, *Journal of Asian Economics*, vol. 64, pp. 101129. http://doi.org/10.1016/j.asieco.2019.07.002

[8] Hazoor HM, Safdar HT, Salman A, Saad BN, (2012) Future of Cooperative Farming in Pakistan, *Journal of Biology, Agriculture and Healthcare*, ISSN 2224-3208, vol 2, No.6.

[9] Huang, Z,.-h., et al., (2015) Situational features and governance structure of farmer cooperatives in China: Does initial situation matter?", *The Social Science Journal*, vol. 53, pp. 100-110. http://dx.doi.org/10.1016/j.soscij.2015.09.003

[10] Suh Jungho, (2015) Communitarian Cooperative organic rice farming in Hongdong District, South Korea", *Journal of Rural Studies*, vol. 37, pp. 29-37. https://doi.org/10.1016/j.jrurstud.2014.11.009

[11] Abate T.G., (2018) Drivers of agricultural cooperative formation and farmers' membership and patronage decisions in Ethiopia", *Journal of Cooperative Organization and Management*, vol. 6, pp. 53-63. http://doi.org/10.1016/j.jcom.2018.06.002

[12] Ajates Gonzalez, R., (2017) Going back to go forwards? From multi stakeholders cooperative to open cooperatives in food and farming", *Journal of Rural Studies*, vol. 53, pp. 278-290. http://dx.doi.org/10.1016/j.jrurstud.2017.02.018

[13] Wacker G John, (1998) A definition of theory: research guidelines for different theory-building research methods in operations management, *Journal of Operations Management*, vol. 16, pp. 361-385.

[14] Adefila James, Madaki Joshua, (2014) Roles of Farmers cooperative in Agriculture development in Sabuwa Local government area of Katsina State Nigeria, *Journal of Economics and Sustainable Development*, ISSN 2222-1700, vol.5, No. 12.

[15] Shen Mingrui, Shen Jianfa, (2018) Evaluating the cooperative and family farm programs in China: A rural governance perspective, *Land Use Policy*, vol. 79, pp. 240-250. https://doi.org/10.1016/j.landusepol.2018.08.006

[16] Matthews B. R., (1922) Electro Farming, or the application of electricity to agriculture, *I.E.E. Journal*,Vol. 60, No. 311.

[17] Chetan DM, Ganesh RR, Jagannnathan S, R Priyatharshini, (2015) Smart Farming System using sensor for agriculture task automation, *IEEE International conference* (TIAR 2015)

[18] Alice J. Norman and R. C. Bowes, (1984) Electricity in the farm dairy: requirements, use and conservation", *Journal of Society of Dairy Technology*, Vol.37, No. 2. https://doi.org/10.1111/j.1471-0307.1984.tb01233.x

[19] Ugo Bardi, Toufic El Asmar, Alessandro Lavacchi, (2013) Turning electricity into food: the role of renewable energy in the future of agriculture, *Journal of Cleaner Production*, vol. 53, pp. 224-23. https://doi.org/10.1016/j.jclepro.2013.04.014

[20] Namrata Chindarkar, Yvonne Jie Chen and Shilpa Sathe, (2017) Impact of Farm electricity supply management on farm households in Gujarat, India, 28 June 2017

[21] Fabio Riva, Emanuela Colombo, (2020) System-dynamics modeling of the electricity-development nexus in rural electrification based on Tanzanian case Study, *Energy for Sustainable Development*, vol. 56, pp. 128-143. https://doi.org/10.1016/j.esd.2020.04.001

[22] V.J.P.D. Martinho, (2020) Relationships between agriculture energy and farming indicators, *Renewable and Sustainable Energy Reviews*, vol. 132, pp. 110096. https://doi.org/10.1016/j.rser.2020.110096

[23] B. D. Simonevan, Bogaardt Marc- Jeroen and Wolfert Sjaak, (2019) Ethics of smart farming: Current questions and directions for responsible innovation towards the future, *NJAS – Wageningen Journal of Life Science*, vol. 90-91, pp. 100289. http://doi.org/10.1016/j.njas.2019.01.001

[24] Sen, S., Ganguly, S., Das, A., Sen, J., Dey, S., (2015) Renewable Energy Scenario in India: Opportunities and Challenges, *African Earth Science*, vol. 122, pp. 25-31, 2015. doi: http://dx.doi.org/10.1016/j.jafrearsci.2015.06.002

[25] Lee Song Ki, Choe Chan Young, (2019) Environmental performance of organic farming:

Evidence from Korean Small-holder soybean production, *Journal of Cleaner Production*, vol. 211, pp. 742-748. https://doi.org/10.1016/j.jclepro.2018.11.075

[26] A.Z. Dhunny, Z Allam, D. Lobine, M.R. Lollchund, (2019) Sustainable renewable energy planning and wind farming optimization from a biodiversity perspective, *Energy*, vol.185 pp.1282-1297, 2019. https://doi.org/10.1016/j.energy.2019.07.147

[27] Forde E., (2017) The ethics of energy provisioning: Living off-grid in rural Wales, *Energy Research & Social Science*, vol. 30, pp. 82-93. http://dx.doi.org/10.1016/j.erss.2017.06.018

[28] Bruno S S, Diana M T, (2019) Innovations for sustainable development: moving towards a sustainable future, *Journal of Cleaner Production*, vol. 208, pp. 325-332. https://doi.org/10.1016/j.jclepro.2018.09.244

[29] Keeley AR, (2016) Renewable Energy in Pacific Small Island Development States: The Role of International Aid and the Enabling Environment from Donor's perspectives, *Journal of Cleaner Production*, vol. 146, pp. 29-36. https://doi.org/10.1016/j.jclepro.2016.05.011

[30] Kaunathilake H, Perera P, Ruparathna R, Hewage K, Sadiq R, (2016) Renewable energy integration into community energy systems: A case study of new urban residential development, *Journal of Cleaner Production*, vol. 173, pp. 292-307. doi: 10.1016/j.jclepro.2016.10.1067

[31] Ian H. Rowlands, (2007) The Development of Renewable Electricity Policy in the province of Ontario: the influence of idea and timing, *Review of Policy Research*, Volume 24, pp. 185-207.

[32] S. Choudhury, A. K. Patra, A. Parida, S. Chatterjee, (2018) Renewable energy capacity estimation for Indian energy sector using energy demand forecasting through Fuzzy Time Series, Advances in Smart Grid and Renewable Energy, *Springer*, pp-551-558. doi.org/10.1007/978-981-10-4286-7_54

[33] A. Parida, D. Chatterjee, (2016) A solar PV augmented hybrid scheme for enhanced wind power generation through improved control strategy for grid connected doubly fed induction generator, *Cogent Engineering*, 3: 1147337. doi.org/10.1080/23311916.2016.1147337

[34] A. Parida, S. Choudhury, S. Chatterjee, D. Chatterjee, (2016) A cost effective trade-off based renewable power augmented energy efficient load model for manufacturing industries for demand side management", *Cogent Engineering*, 3: 1239299. doi.org/10.1080/23311916.2016.1239299

[35] A. Parida, S. Choudhury, S. Chatterjee, D. Chatterjee, (2016) A rule based electrical energy distribution model for energy efficiency in technical institutions: A case study, *Energy and Buildings*, 126, pp-508-516. doi.org/10.1016/j.enbuild.2016.05.069

[36] S. Choudhury, A. Parida, R. M. Pant, S. Chatterjee, (2016) GIS augmented computational intelligence technique for rural cluster electrification through prioritized site selection of micro-hydro power generation system, *Renewable Energy,* 142, pp-487-496. https://doi.org/10.1016/j.renene.2019.04.125

Proposed Cooperative Farming as a Catalyst to Livelihood Augmentation for the Marginal Farmers in Majuli Island

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Abstract:

Cooperative farming is an effective mechanism for sustainable development of the farming community. However, proper implementation criterion and technological intervention is essential to improve the economic sustainability and to make it popular among the farming groups. A case study has been carried out in Majuli, the world's largest river island in Assam, India. It has been observed that the peoples of Majuli are mainly involved in farming and they adopt their present system of farming. On the basis of primary and secondary data collected, this paper highlighted how economically sustainable and technologically empowered cooperative approach in farming will be beneficial for marginal farmers in Majuli. Their conventional farming model has been systematically studied, appropriately analyzed and the same has been improved through the proposed cooperative farming model without affecting their culture and traditional values.

Key words: *Cooperative farming, Marginal farmers, Livelihood, Majuli*

1. Introduction

Majuli has been declared as the world's largest river island. It is located within the river Brahmaputra in Assam of Indian subcontinent. The scenic beauty of this island is enriched with flora and fauna. As an isolated island with its natural beauty makes the island a tourist hub for peoples from different parts of the world. On a frequent interval, both domestic and overseas tourists creates avenues for livelihood. However, only tourism is insufficient for minimum livelihood level for the farmers in the said remote location. Though very less in number, the small scale cottage industries provide limited employment in this region. It has been observed that the dependency upon agriculture is considered to be prime source of their livelihood. Being an isolated island, the connectivity to the nearby market place for transaction of different resources often create hurdle for the marginal farmers. The marginal farmer's cohesive approach like other places of the world can also be considered to bridge the gap.

Cooperative farming or collective farming is not a new concept in agriculture as it is used in various parts of world. It refers to a system where each member or farmer remains the owner of his land individually but farming is carried out jointly. Here, profit and loss is distributed among the member according to the ratio of land owned by them. Cooperative is a kind of farming operation where, individuals, on their own holdings perform farming practices jointly with the help of certain common agencies formed. These agencies help in purchase and collection of certain farming inputs like fertilizers, seeds, equipment etc., on behalf of farmers, and also promote sale of agricultural outputs. This paper focuses on the rice farming as around 90% of farming land in Majuli depends on rice cultivation. Majority of families in Majuli who does farming uses traditional system for farming and getting low benefit compared to those who are into cooperative or modern farming system. Hence the main objective of this paper is to understand the applicability of cooperative system into the area of No.1 Borgayan village of Majuli district and asses the range of cooperative scenarios using collected data.

The highlights of the presented paper can be summarized as follows;

(1) The status of the existing livelihood in general and livelihood from agricultural practices in particular has been systematically analysed in Majuli island.

(2) Reviews the literature associated with the topic of cooperative or collective farming.

(3) Proposes an economically sustainable cooperative farming model without affecting their culture and traditional values for improved livelihood in said region.

1.1. *Research Methodology*

The research was carried out in No.1 Borgayan village of Majuli District, Assam. It is a medium size village with a population of around 1320. Approximately 247 families residing according to the population census 2011. The literacy rate of this village is very low compared to Assam. Borgayan village is administrated by *Sarpanch* (head of village), an elected representative of village. The main source of income here is from farming almost everyone here depends on agriculture. The main cultivation is rice and is mainly grown 3 types of rice on the basis of season. Other than this they practice kitchen gardening for their daily needs. Data used for this research work were both primary and secondary in nature. Primary data collection was done using simple random sampling technique through interview method. During the survey agricultural field were visited and during the process interacted with around 50-60 farmers at work. Thus, data mainly collected first hand from the marginal farmers. Other sources for data collection from primary data were field visit, and personal observation. The secondary data used for this study was from different sources such as e-journals, census, journals, various publications, reports, recent articles.

1.2. *Cooperative farming at a glance*

The term "agricultural cooperatives" is classifies into two groups: agricultural production cooperatives which helps in pooling of land and resource and agricultural service cooperatives provides certain services needed in agriculture such and storing, warehousing, etc. when market fails to provide agricultural inputs and services at reasonable price, cooperatives forms and expands. Cooperative movement has reported success in Kenya, Uganda, Jordan, Nicaragua, Romania, Israel and Germany.

Fig. 1 - Author during interaction with the respondents.

Agriculture the core area where cooperatives are mostly used as around 32% of global market share in farming sector belongs to "cooperatives" (Millovanovic, 2018). Cooperatives helps in formation of society and thereby empowers the members to encourage working and improving quality of their life and economic opportunities.

This cooperative system aims at increasing production and incomes of farmers through linking them with markets and other necessities. It may help in solving all the uneconomic and social holdings, by providing employment by reaping all the benefits of large scale farming. Under cooperative farming bulk surplus can be also be marketed. This will also help in releasing workers from farming operations to non-agricultural operations and thereby, increasing scope for economic progress. The basic idea behind pooling of land is to use the scare resources jointly so that every bit of land is used to the best of its fertility.

Cooperative farming has conducted in various countries like UK, France, Sweden etc., and has proved various benefits such as every bit of land is used as a result wastage of land is very little. Cooperative society can purchase various machineries which small scale farmers can't afford that helps in increasing per acre yield. It also catalyzes in getting timely agricultural inputs. Cooperative farming also helps in increasing the love and brotherhood among farmers. Cooperative model will be beneficial to government also as it will make tax collection and distribution of resources easier as compared to individual marginal farmers.

1.3. *Review on cooperative farming in a global prospective*

Cooperative farming has been the area of research for many researchers across the globe. The paper reviews few to highlight the recent trends of it in different perspectives. Adefila and Madaki (2014) in their research paper "roles of farmers' cooperatives in agricultural Department area of Katsina State, Nigeria" revealed that farmers' cooperative society are proved to be very helpful to farmers and agricultural department but certain factors influence their role performance. Study says that serious efforts to be made in order to identify the issues that are pushing back the growth and development of farmers cooperatives.

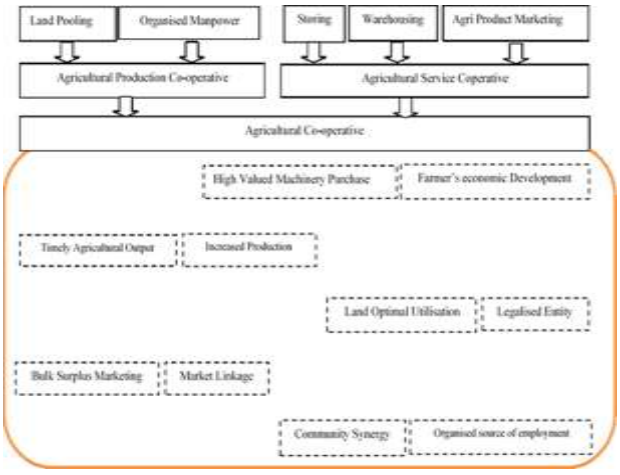

Fig. 1 - Conventional Cooperative Farming.

Gong, Battese and Villano (2019) in the publication "Family Farm plus Cooperatives in China: Technical Efficiency in Crop Production" says that cooperatives shows more efficiency compared to the other one. They also found that members of cooperative helps farmers to learn more advanced technology and also benefit in productivity enhancing practices.

They also proved that age and educations also matters and contribute t technical efficiency. Jungho (2015) in his work on "Communitarian cooperative organic rice farming in Hongdong District, South Korea" proved that cooperative organic rice farming helped in increasing the income of households, owing to a strong demand for organic food. They also says that cooperative farming is a sustainable option for individual agriculture. It can be effectively executed with voluntary effort of local individual farmers. M. Vladimer and S. Lubos (2018), in their study "cooperative rice farming within rural Bangladesh" had described rice growing practices of the area and presented a potential benefits cooperative farming using four scenarios.

S. M. Hazoor, T. H. Safdar, A. Salman, and N. B. Saad in their paper (2012) "Future of Cooperative Farming in Pakistan" in their study they proved that cooperative farming is more beneficial and more economical than individual farming.

But they also claims that long term sustainability of cooperative is affected by certain factors. S. Swagemakers, M. Dolores, M. Pierluigi, V. Flaminia and S. C. Wiskerke (2018) in their paper " Exploring Cooperative place-based approaches to restorative agriculture" has highlighted how cooperative approaches allow public and private regulatory system to support ecological transitions. And it also highlights the competitive advantage to farmers and how to enable an increase in income from farming.

1.4. *A Glimpse of Majuli*

Majuli is located in the mid of river Brahmaputra is Assam and recently

declared as a District of Assam. Indian government has also nominated Majuli of inclusion in the cultural landscape category in the list of UNESCO World Heritage. Peoples of Majuli are mainly dependent on agriculture for their livelihood. Majuli is one of the economically backward place of Assam in industrial sector.

Fig. 3: Public transportation at Majuli.

Besides, agriculture, cottage and small scale industries provide employment in the district. This district island covers an area of 352 square km and has around 1, 67,304 population. Around 75% of total population depend on agriculture. Other than rice peoples here also cultivate wheat, potato, oil seeds pulses, but in a limited amount. Around 41.43% of the area is used for agriculture. Farmers here has very small area for cultivation, per farmer has around 0.95 hector of land which is very less (Das, 2017).

The village we have selected for the survey is Borgayan No. 1. Its population according to the census 2011 is 1320 (census, 2011). The main crop cultivation of this village is rice and mustard. The crop chart is as follows:

Table 1 -An example of a table.

Crops	Sowing	Harvesting
Ahu dhan (rice)	Jan	July
Baw (rice)	March-April	Nov-Dec
Mustard	Aug-Sep	Feb-March
Chana Dal	Nov	Nov

The most profitable crops are *ahu-dhan* and mustard. Apart from this, they are also famous for black gram cultivation and curd. Peoples here are mainly into farming and their other daily needs are met by livestock and kitchen gardening. They grow vegetables in a very small amount as much as needed to meet their daily needs. Their other sources of incomes are from cattle, livestock's, fish ponds etc. and some also works as labors. Their per day labor charge for 8 hours work is US$3.6/-. Farmers here carry out their farming using traditional system and equipment, no modernization happened till this date as they don't even used any mechanized farm machinery. Agricultural profits and loss completely depends on the climatic conditions, which sometimes leads to a complete loss situation. Due to climatic condition, the land and harvesting, remains the same.

1.5. *Case study of Borgayan Village of Majuli*

From the study it is found that the villages' main source of income is from agriculture. Farmers here does their farming using traditional system and equipment, absence of modern practices of water shed management has also been observed. Around 5% of the farmers uses diesel pumps for irrigation purpose and rest 95% of them completely depending on climate for irrigation. Based on the land availability, some farmers does multi cropping based on the season mainly for rice cultivation.
Mustard is the only crop they sell for money. Brokers collect mustard from the farm itself and sell it to mill. Here, farmers are getting very less profit and brokers are benefited.

Fig. 4: Bamboo made pool at Majuli.

After harvesting, these grains are stored in a Bharl, a small room like structure, made up of bamboo and dried grass. Based on the need, farmers take these grains to rice mill, process it there using diesel engine. The waste or rest rice husk are feeded to cattle. Land owners are having their own lands, when farming is done individually, the cost of agricultural inputs need to bear by their own, which is high sometimes for small scale farmers. They have to face difficulty in irrigating their land, setting tube wells, etc. as their land is attached to other land. Soil erosion is one of the main issue here. In addition, it is also prone to flood.

When such issue occurs the whole land sometime goes in a loss situation and the respective individual farmers have to bear the whole loss. Presently the area is divided with boundaries and farming is carried out in their respective land. Very small and scattered land pattern has the problem of irrigation, as well as drainage issues. A collaborative cooperative farming can act to catalyze the livelihood of the marginal farmers.

1.6. *Proposed methodology to uplift the livelihood of marginal farmers*

Cooperative farming or collective farming is a system of farming here the land and resources are pooled together.

This technique is being used is various parts of the country and is proved to be effective and much more beneficial compared to the traditional one (Gong, 2019, Swagemakers, 2018).

Fig. 5: Borgayan Village of Majuli.

In this system, each members of the farm will remain the owner of their land individually, but farming will be done jointly. Profit and loss from agriculture will be divided on the basis of ratio of land, one holds (Milovanovic, 2018). Wages will also be distributed on the basis of number of days they worked (Suh,2015). Under this system, the land which was earlier used for boundaries will be removed and all the lands will be combined together. By joining al the small and marginal farmers, the member of cooperative can earn profit of large scale farming. Apart from this, the feeling of brotherhood and spirit of synergy will be there. It will further increase the feeling of friendship n thereby collective thinking and collective action (Sabir, 2012).

For this to be implemented, the first step is to formulate a non-governmental organization (NGO) or a Self Help Group (SHG). It can be formulated by picking up some farmers. These farmers will form a unit. And the entire farm will be managed under this unit. This small unit can then act as a society. Once this society get registered with the government, they will get all the related agricultural products, agricultural inputs and other modern equipment at a subsidy rate. Loan and other financial helps can be taken from this society (Milovanovic, 2018, Swagemakers, 2018). Agricultural loss due to natural calamities can easily be recovered. This benefit, individual farmers can't enjoy.

This same society formation can be done without the interference of government. Society is the farmer members, can buy agricultural inputs on a bulk basis and can be used as a unit in every land. The electricity charges can be shared. The surplus food can then transported to market and thereby earn profit. This profit can then equally divided among the members of society.

1.7. *Proposed Integrated Farming Cooperative Model*

Significance of the proposed integrated model is as follows: a) Trainers will be trained:

This is the initial step in proposed integrated model. Under this the young farmers of the particular village will be given training. The trainers will be, old and experienced persons who have better knowledge and well versed with the systems. These ideas and insights can be transferred as "training" to young workers who are new to respective area of work.

b) Identification of domain consultant:

A consultant is recruited from outside the village who will play the role of mediator between the experienced trainers and young trainees. This consultant will be observing the work and trainings and will also give his inputs when need arise.

c) Selection of team leader:

Under this, a team leader is selected among the youths of the village itself. These leaders will lead the team and will also play a role in conflict management. Formation of team leaders may help in convincing the locals while making a new decision or introducing a new technique.

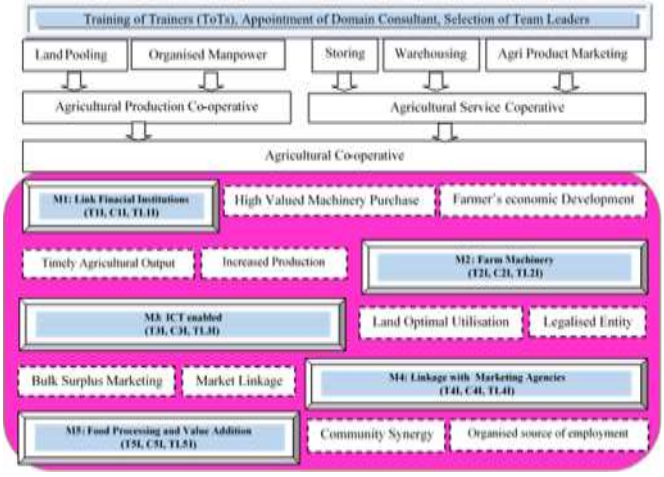

Figure-6: Proposed integrated model for farming Cooperative

These three techniques introduced in proposed farming cooperative will help in properly distributing the works among respective groups and thereby getting clarity over work. For a clearer view and a systematic flow of activities, four different modules are introduced. These modules are nothing but a group of leaders who will take the responsibility of overall look after and supervision of the respective job assigned to them.

Under each module, there will be three persons:
i) Trainer's Intervention (TI): This person can be any one from the "trainers group", on a rotation wise for quarterly basis.
ii) Consultant Intervention (CI): a consultant with respected to their area of experience will be included in the module.
iii) Team leader supervision (TL): a team leader on a rotation basis will be selected for over all supervision of the works being carried out.
Each module will be related to certain activity.

- Module 1: Linkage with financial institution: this module will carry out the finance related activities such as banking, loans, rents, etc.
- Module 2: Linkage with marketing agency: this module will be carrying out the activities related to purchasing and selling of agricultural products, such as purchasing of agricultural inputs like seeds, fertilizers, etc. and marketing the surplus (if any).
- Module 3: ICT Enabled: ITC is nothing but information, communication and technology. Under this, the activities related to technical groups, quoting related information's, communicating, etc. are done and supervised.

1.8. *Conclusion*

This paper has analyzed systematically the present agricultural practices in Majuli of Assam, India and successfully proposed a cooperative based, technologically empowered farming model to improve the sustainable livelihood of the beneficiaries in the said region. Also, the paper highlighted appropriately the benefits of cooperative farming with reference to the farmers of Majuli in particular and farmers in other regions in general. This system will not only increase the standard of living but also increase the feeling of friendship, cooperation and there by achieves a synergy in the agricultural sector.

Acknowledgements

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REFERENCES

https://www.census2011.co.in/data/village/293393-borgayan-no-1-assam.html.

Das B, (2017), Cottage and small scale industries in Majuli and its challenges: A study, International Journal of Advance Education Research, Vol 2, issue 4, 51-53.

Das, B., (2017). An overview of the economic condition of Majuli, the largest inhabited river island of the world, International Journal of Interdisciplinary and Multidisciplinary Studies, Vol 4, No.3, 91-96.

Gong T (Charles), Battese G E, Villano R A, Family Farms Plus (2019). Cooperatives in China: Technical Efficiency in Crop Production, Journal of Asian Economics, http://doi.org/10.1016/j.asieco.2019.07.002. (Article in press).

Goswami R. (2013), Arsenic in the groundwater of Majuli- The largest river island of the Brahmaputra: Magnitude of occurance and human exposure, Journal of Hydrology, Vol. 518, Part C, 354-362. http://dx.doi.org/10.1016/j.jhydrol.2013.09.022.

James, A., Joshua, M., (2014) Roles of Farmers' Cooperatives in Agricultural Development in Sabuwa Local Government Area of Katsina State, Nigeria, Journal of Economics and Sustainable Development, Vol 5, No. 12,80-87.

Milovonovic, V., Smukta, L., (2018). Cooperative rice farming within rural Bangladesh, Journal of Cooperative Organization and Management, 6, 11- 19.

Nayak, D. K., Das, M., An assessment of Redistribution of Population in Majuli Island due to river bank erosion, Department of Geography, North Eastern Hill University, Shillong.

Sabir ,H. M., Tahir, S. H., Arshad, S., Nasir, S. B., (2012). Future of Cooperative Farming in Pakistan, Journal of Biology, Agriculture and Healthcare, vol 2, No. 6.

Sarma, J. N. , Phukan, M. K., (2004). Origin and some geomorphological changes of Majuli Island of the Brahmaputra River in Assam, India, Geomorphology, 60, 1-19.

Silvestre, B. S., Tirca, D. M., (2018). Innovation for sustainable development: Moving toward a sustainable future, Journal of Cleaner Production, 208, 325-332.

Suh, J., (2015). Communitarian cooperative organic rice farming in Hongdong District, South Korea, Journal of Rural Studies, 37, 29-37.

Swagemakers, P, (2019). Exploring cooperative place-based approaches to restorative agriculture, Journal of Rural Studies, 191-199.

Appendix 3	**List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings**

FIELD TRAINING SESSIONS ORGANIZED

S. No	Date	Venue	Workshop/ Training Session Theme	No. of participants	
				Male	Female
1	24-01-2019	Sakiang	a) Workshop on climate-resilient agricultural Practices-I; b)Training Need assessment-I	20	13
2	24-01-2019	Pan	a) Workshop on climate-resilient agricultural Practices-II; b)Training Need assessment-II	14	15
3	25-01-2019	Old Mengio	a) Workshop on climate-resilient agricultural Practices-III; b)Training Need assessment-III	21	14
4	25-01-2019	Kullung	a) Workshop on climate-resilient agricultural Practices-IV; b)Training Need assessment-IV	10	16
5	26-01-2019	Pacho	a) Workshop on climate-resilient agricultural Practices-V; b)Training Need assessment-V	12	15
6	26-01-2019	Nyopang	a) Workshop on climate-resilient agricultural Practices-VI; b)Training Need assessment-VI	20	12
7	27-01-2019	Paga	a) Workshop on climate-resilient agricultural Practices-VII; b)Training Need assessment-VII	15	12
8	28-01-2019	Heyang	a) Workshop on climate-resilient agricultural Practices-VIII; b)Training Need assessment-VIII	14	10
9	09-03-2019	Sakiang	Awareness on Indian standards relevant to agriculture and food department-I	23	08
10	09-03-2019	Pan	Awareness on Indian standards relevant to agriculture and food department-II	14	17

Shri Phill Biman
Junior Project Fellow

Shri Nabam Tahi
Gaon Burah

Dr. S. Choudhury
Project PI

FIELD TRAINING SESSIONS ORGANIZED

S. No	Date	Venue	Workshop/ Training Session Theme	No. of participants	
				Male	Female
11	10-03-2019	Old Mengio	Awareness on Indian standards relevant to agriculture and food department-III	20	24
12	11-03-2019	Kullung	Awareness on Indian standards relevant to agriculture and food department-IV	22	06
13	12-03-2019	Pacho	Awareness on Indian standards relevant to agriculture and food department-V	23	18
14	23-04-2019	Sakiang	Roadmap for livelihood-I	17	11
15	23-04-2019	Pan	Roadmap for livelihood-II	12	09
16	24-04-2019	Kullung	Roadmap for livelihood-III	22	13
17	25-04-2019	Sakiang	EDP on in large cardamom and other multilayer farming-I	30	32
18	26-04-2019	Lokang	EDP on in large cardamom and other multilayer farming-II	11	09
19	27-04-2019	Paga	EDP on in large cardamom and other multilayer farming-III	08	12
20	28-04-2019	Paga	EDP on in large cardamom and other multilayer farming-IV	12	20

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FIELD TRAINING SESSIONS ORGANIZED

21	29-04-2019	Pan	EDP on in large cardamom and other multilayer farming.	09	12
22	30-04-2019	Pan	Workshop on cooperative farming society for the nearby cluster villages-I	14	07
23	16-06-2019	Sakiang	Workshop on cooperative farming society for the nearby cluster villages-II	20	06
24	16-06-2019	Pacho	Workshop on cooperative farming society for the nearby cluster villages-III	13	10
25	18-06-2019	Sakiang	a) Workshop on regulatory framework of cooperative farming society (CFS)-I b) Document collection from the interested members for the CFS-I	09	12
26	18-06-2019	Old Mengio	a) Workshop on regulatory framework of cooperative farming society (CFS)-II b) Document collection from the interested members for the CFS-II	12	11
27	19-06-2019	Kullung	a) Workshop on regulatory framework of cooperative farming society (CFS)-III b) Document collection from the interested members for the CFS-III	18	14
28	20-06-2019	Balliang	a) Workshop on regulatory framework of cooperative farming society (CFS)-IV b) Document collection from the interested members for the CFS-IV	10	10
29	20-06-2019	Pan	a) Workshop on regulatory framework of cooperative farming society (CFS)-V b) Document collection from the interested members for the CFS-V	12	08
30	21-06-2019	Lokang	a) Workshop on regulatory framework of cooperative farming society (CFS)-VI b) Document collection from the interested members for the CFS-VI	20	11
31	22-06-2019	Paga	a) Workshop on regulatory framework of cooperative farming society (CFS)-VII b) Document collection from the interested members for the CFS-VII	12	20

Shri Phill Biman
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Appendix 4 List of New Products

Pic 16: Event National Buyers and Sellers meet, Unveiling and launching of organic products like ginger, dried large cardamom under thebanner of Panior Multipupose cooperative society limited.

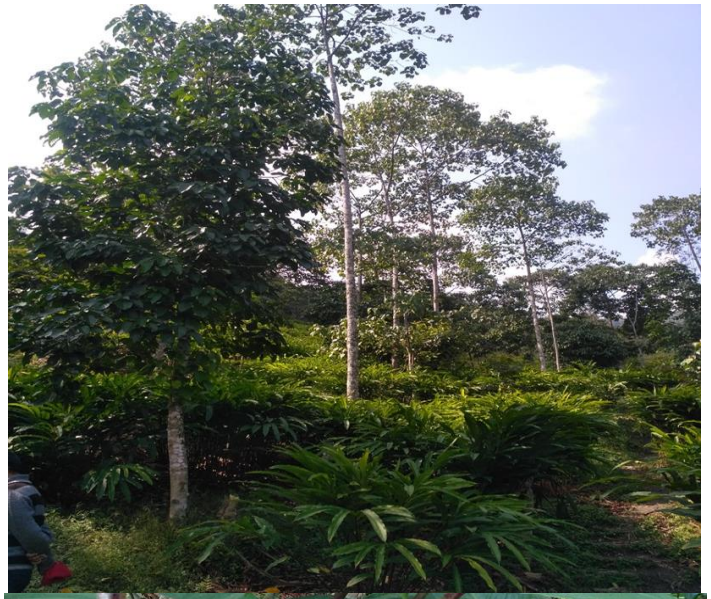
Pic 18: Launching of Himalayan hills wild honey under the banner of Paniar Multipurpose Cooperative Society

Pic 19: Paniar Farmers' Cooperative Society participating in the World honeybee day and Mediabriefing for products like large cardamom, ginger, guava products, and wild honey,

Appendix 5 **Copies of the Manual of Standard Operating Procedures (SOPs) developed**

- Waterlogging needs to be avoided.
  (Iss mamab twptel down yo)
- Cannot grow in direct contact with the sun.
  (Donye direct dwda mamab. Doyum ho doam te)
- The plantation of large cardamom starts in the month of June, when the field gets enough rain.
  (Elaci ledwn June pol ho, lele nyado hod pol ho)
- It requires continuous irrigation during the dry season and 4 to 6 months after harvest.
  (Tapam pol hoi ss jidwb nidwn ho mode ho nyodwn, kedw path teldowden pol 4 to 6 alche puho koiyu kam iss jiteb nyido)
- After planting seeds in the field, the large cardamom plant takes 3 to 4 years for bearing the fruits.
  (Lilo koyu 3 to 4 anyi koyeb akkhe lekhi dewn).

- Planting is done during June-July when there is enough moisture in the soil. The land selected for planting is cleared of all undergrowth, weeds, etc., for new planting, or if it is replacing, old plants from time to time.
  (June-July polwn nah lidwn lit, ho modh lo kede juja dewn ked lidu ko ham hikibja maha chod)
- Pits of size 30×30×30 cm are prepared on the contour of the hill at a spacing of 1.5× 1.5 m after the onset of monsoon showers.
  (Lidh ko ung ham 30×30×30 cm koigab dwth ho koku, 1.5×1.5 m apatal dombto)
- Wider spacing of 1.8×1.8 m is recommended for robust cultivation.
  (Ado nge 1.8×1.8 m ado dombto)
- The pits are left for weathering for a fortnight and filled with topsoil mixed with cow dung or compost at the rate 1-3 kg per pit.
  (Ungam dutel loligola lape ngo dombto. Ho koyeb ao kedw lola noge sw ngam mayetel akin ungho 1-3 kggob lwte)
- Seedlings/suckers are planted in the middle of the pit. *(Alee ham lopa rarr ho lilite)*
- Care should be taken not to plant the seedling/rhizomes very deep in pit.
  (Leedw mode hohegab toh el ham urwjab talw mab)
- After planting the seedling/suckers may be staked and the base of the plant is mulched with dry leaves.
  (Lee ho koyu, ao ho sekubo nana noge martub tho).



Exposure to direct sunlight during the day is very harmful for large cardamom. It causes sunburn on leaves and significantly reduces the content of soil moisture.
(Donyi dudha manalab hw al madand. Owk donyduh taiyin ho latgab kedeo kam pwtw taiyin ham heb niye mab)

Curing is important for obtaining the quality capsules of large cardamom. Curing is usually associated with the balance of color, humidity, and maturity depending on the levels of capsule maturity at harvest time.
(Elchi swn lwkw ham puha pura toh, dwrubjab ahe aldwne pudub kam al dwne).

The cardamom capsules should be dried by indirect hitting. The capsule without a tail gets a higher price. Generally, tails are removed with a scissor of the knife.

(Elchi khin ham maho to)

Appendix 6 Details of Technology Developed

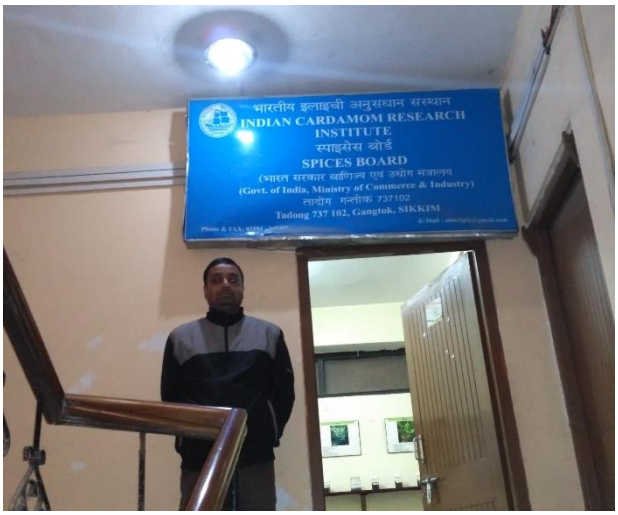
Green energy based electric dehydrator

Appendix 7 Pictures of the project activities

Pic 1: With the CEO, ArSLM, Itanagar.

Pic 2: With the officials of NABARD, Itanagar.

Pic 3: With the officials of the Spice board of Itanagar, and Ziro of Arunachal Pradesh.



Pic 4: With the officials of the Indian Cardamom Research Institute at Gangtok, Sikkim.

Pic 5: At the Assistant Registrar, Cooperative Society of Arunachal Pradesh.

Pic 6: With the bank officials of North East Small finance Bank along with scientists from GBPNIHESD (implementing partner).

Pic 7: Steering committee meeting with the store purchase and finance section of NERIST and representative of implementing partner.


Pic 8: Bhati at Indian Cardamom Research Centre, Gangtok, Sikkim.

Pic 9: Dryer installed by the department of horticulture at project site under RKVY(2011-12).

Pic 10: Traditional large cardamom dryer by the local farmers.

Pic 11: Inspection of Electric Dryer installed by a local entrepreneur.

Pic 12: Inspection of Drying process by marginal farmers.

Pic 13: Bumblebee Awareness program, at Mengio with village representatives.

Pic 14: Environment awareness cum Tree Plantation Program at Mengio.

Pic 15: Official Handing over of Farmers Cooperative registered certificate at NERIST Nirjuli by chief guest Prof. R. M. Pant, Director, NIRD &PR, Guwahati.

Pic 16: Event National Buyers and Sellers meet, Unveiling and launching of organic products under thebanner of Panior Multipupose cooperative society limited.

Pic 17: Two days Training of Trainer (TOT) with Cooperative members at Sikang Mengio.

Pic 18: Launching of Himalayan hills wild honey under the banner of Paniar Multipurpose Cooperative Society

Pic 19: Paniar Farmers' Cooperative Society participating in the World honeybee day and Mediabriefing

Pic 20: Solar energy park at NERIST.

Pic 21:NMHS sponsored a National seminar on tribal empowerment through the entrepreneurship of indigenous produced products -2019, May 9-10, 2019 at NERIST in collaboration with Tezpur University, and the Northeast regional centre of Govind Ballabh Pant 'National Institute of Himalayan Environment(NIHE).

Pic 22: Exposure Trip for marginal farmers to the progressive farmland.

Pic 23: Independence day celebration at Mengio.

9 ACKNOWLEDGEMENT

First of all, I would like to express my sincere gratitude to my supervisors, Prof. Rajive Mohan Pant and Prof. Saibal Chatterjee for expert guidance and generous support. I cannot forget their learned guidance during my period of Project tenure. Without their help, it wouldn't have been possible to present my work with so much of interest and patience.

I would like to extend my sincere gratitude towards Er. Kireet Kumar Sir for giving the opportunity through this project. I would also like to thank Shri Jagdish Pandey Sir, Shri B.C. Pandey Sir, and Shri Dinesh Bisht Sir for continual support and help during the whole tenure of the project.

I would like to thank Prof. H.S. Yadav, Director, NERIST for his immense moral support and encouragements. You are my real source of inspiration.

I would like to take the opportunity to pay my sincere respect to Er. Mahendra S. Lodhi, Dr. Wishfully Mylliemngap, and Dr. Satish Chandra Arya of G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD), Itanagar, Arunachal Pradesh; and Dr. Kshirod Kumar Das of Tezpur University, Dr. A. Parida of NERIST, all the faculty members, technical staffs, and officers of electrical engineering and centre for management studies, officials of Finance and store and purchase section. I owe special thanks to Prof. P. P. Dabral, Professor of Department of Agricultural Engineering of NERIST for his guidance and endless support during my research work.

I greatly appreciate the support from my project staffs especially Mr. Phill Biman and encouragement received over the years from gaon burahs of Mengio circle, CEO, ArSLM, Itanagar, officials of NABARD, Itanagar, officials of the Spice board of Itanagar, and Ziro of Arunachal Pradesh, Shri K. Goswami of Axomurja, and scientists of Indian Cardamom Research Centre, Gangtok, Sikkim. I owe gratitude to all the villagers of Mengio circle for their continuous support. I would also like to thank Dr. B. Sharmah, HoC, CMS, NERIST, and Dr. M. Mall, Assistant Professor of CMS. My special thanks goes to MBA students, research scholars of NERIST who have helped me in various ways like writing research papers, helping in market survey in due course of time. I thank all my colleagues. It was only

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because of their presence that the work place became such a lively and friendly environment to work and enjoy.

There are many people who have supported me throughout the course of my project work. I would like to thank my near and dear friends. I would like to thank your friendship and technical advice throughout. I would not have made it without you peoples.

I owe my heartfelt thanks to my Bada Bapa, and my Bada Bou for their blessings. I thank my sister-in-law Kunmun and brother Debu for their continuous encouragements. Special thanks goes to my wife Mrs.Poornima Choudhury for her love, continuous encouragement and giving valuable suggestions for improvement of the report. I would also like to acknowledge the help rendered by her in drawing diagrams and proof reading of this project report.I thanks my sons, Om and Anshu for bearing with me and supporting me in all possible manners. I also thank all in my family and my friends for their continual support and encouragements for completing my first project work.

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(Shibabrata Choudhury)

Annexure-I

Consolidated and Audited
Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: 2018-2021

1.	Title of the project/Scheme/Programme:	Large Cardamom and Other Multilayer Innovative Farming in Mengio Circle of Arunachal Pradesh and Its Impact on Sustainable Rural Livelihood
2.	Name of the Principle Investigator & Organization:	Dr. Shibabrata Choudhury Centre for Management Studies North Eastern Regional Institute of Science and Technology (NERIST) Nirjuli, Arunachal Pradesh-791109
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	Ref. No.: GBPNI/NMHS-2017-18/SG15 Date: 28-03-2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	₹19,46,000.00 received on 4th September, 2018.
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	₹19,46,000.00

6.	Actual expenditure (excluding commitments) incurred during the project period:	₹15,08,400.00
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	₹5,17,264.00 amount returned vide cheque number 047140 of SBI, dated 17-06-2022.
8.	Balance amount available at the end of the project:	₹5,17,264.00
9.	Balance Amount:	₹4,37,600.00
10.	Accrued bank Interest:	₹79,664.00

Certified that the expenditure of **₹15,08,400.00 (Rupees Fifteen Lakhs Eight Thousand and Four Hundred only)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date: 01-12-2022

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

01.12.2022

(Signature of Head of the Institution)

[North Eastern Regional Institute of Science and Technology, Arunachal Pradesh]

Statement showing the expenditure of the period from

Sanction No. and Date :Ref. No.: GBPNI/NMHS-2017-18/SG15 Date: 28-03-2018

1. Total outlay of the project : ₹15,08,400.00

2. Date of Start of the Project : 28-03-2018

3. Duration : 3 years

4. Date of Completion : 28-03-2021

a) Amount received during the project period : ₹19,46,000.00

b) Total amount available for Expenditure : **₹19,46,000.00**

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1	Salaries	396000	490426	-94426
2	Travel (Domestic)	200000	146243	53757
3	Consumable			.00
4	Contingency	50000	45000	5000
5	Activities & Other Project cost	500000	148400	351600
6	Institutional charges/Overhead			.00
7	Accrued bank Interest			79664
8	Equipment	800000	678331	121669
	Solar Grid-tied PCW inverter 10kW (Delta)		222000	
	Polycrystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW including installation and commissioning		200000	

	Solar PV supported electric dryer		256331	
	GRAND TOTAL	1946000	1508400	517264

Certified that the expenditure of ₹15,08,400.00 **(Rupees Fifteen Lakhs Eight Thousand and Four Hundred only)** mentioned against Sr. No.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date: 01-12-2022

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

1.12.2022

(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date

COMPETENT AUTHORITY

NATIONAL MISSION ON [illegible]

Annexure-II

Consolidated Interest Earned Certificate

A consolidated interest amount of ₹ 79,664 (Rupees Seventy Nine Thousand Six Hundred Sixty Six only)has been earned in FY 2018-19, 2019-20, 2020-21.

(Signature of Principal Investigator)	(Signature of Registrar/ Finance Officer)	(Signature of Head of the Institution)

01.12.2022

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: National Mission on Himalayan Studies (NMHS), Almora, Uttarakhand.

1. Sl. No. 1 & 2
2. Name of Grantee Institution: North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh
3. No. & Date of sanction order: PUR/167/NMHS/SC/CMS/2018-19 DATED 19-02-2019 (Project registrar page no- 06, 08, 10, 12, 14, 16, 18, and 20)
4. Amount of the Sanctioned Grant: ₹8,00000/- (combined value for Sl.no 1, 2, & 3)
5. Brief Purpose of the Grant: Regarding Grid connected distributed renewable electrification
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: transferred to NERIST
7. Particulars of assets actually credited or acquired: acquired
8. Value of the assets as on : ₹ 4,22,000/- (Booked value without depreciation)
9. Purpose for which utilised at present : both academic demonstration & electrification to NERIST
10. Encumbered or not : Not encumbered
11. Reasons, if encumbered : Not applicable
12. Disposed of or not : Not
13. Reasons and authority, if any, for disposal: Not applicable
14. Amount realised on disposal: Not applicable
15. Any Other
16. Remarks:

Name of the Sanctioning Authority: National Mission on Himalayan Studies (NMHS), Almora, Uttarakhand.

1. Sl. No. 3
2. Name of Grantee Institution: North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh
3. No. & Date of sanction order: multiple dates

4. Amount of the Sanctioned Grant: ₹8,00000/- (combined value for Sl.no 1, 2, & 3)
5. Brief Purpose of the Grant: Regarding Grid connected distributed renewable based large cardamom dryer
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: transferred to NERIST
7. Particulars of assets actually credited or acquired: acquired
8. Value of the assets as on : ₹ 2,58,331/- (Booked value without depreciation)
9. Purpose for which utilised at present : both academic demonstration & practical usage at NERIST
10. Encumbered or not : Not encumbered
11. Reasons, if encumbered : Not applicable
12. Disposed of or not : Not
13. Reasons and authority, if any, for disposal: Not applicable
14. Amount realised on disposal: Not applicable
15. Any Other
16. Remarks:

(PROJECT INVESTIGATOR)

(Signed and Stamped)

01.12.2022

(FINANCE OFFICER)

(Signed and Stamped)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-IV

List of Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details
1	Solar Grid-tied PCW inverter 10kW (Delta)	1set		₹2,22,009.4	
	a) Ms ground mounting structure for 5 kW				
	b) AJ Box				
	c)16 mm wire				
	d) 4 mm wire				
	e) 20 mm wire				
	f) LA, GI Pipe, GI Strip, for earthing.				
	g)MCB with fitting				
	h) SPT single				
	i)25 mm PVC pipe				
	j) MC4 connector				
	k) DC Solar wire				
2	Poly crystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW including installation and commissioning	1set		₹2,00,000.25	
3	Electric Dryer	1 no		₹2,56,331.00	

(PROJECT INVESTIGATOR)
(Signed and Stamped)

01.12.2021

(FINANCE OFFICER)
(Signed and Stamped)

(HEAD OF THE INSTITUTION)
(Signed and Stamped)

Annexure-V

Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department

To,

The Convener, Mountain Division

Ministry of Environment, Forest & Climate Change (MoEF&CC)

Indira Paryavaran Bhawan

Jor Bagh, New Delhi-110003

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "LARGE CARDAMOM AND OTHER MULTILAYER INNOVATIVE FARMING IN MENGIO CIRCLE OF ARUNACHAL PRADESH AND ITS IMPACT ON SUSTAINABLE RURAL LIVELIHOOD" funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

This is hereby certified that the following permanent equipment purchased under the aforesaid project have been transferred to the Implementing Organization/ Nodal Institute after completion of the project:

1. Solar Grid-tied PCW inverter 10kW (Delta)
2. Ms ground mounting structure for 5 kW
3. Polycrystalline Solar PV module 315/320/300/265 watt(Vikram)5 kW
4. Electric Dryer

01.12.2022

Head of Implementing Organization:

Name of the Implementing Organization:

Stamp/ Seal:

Date:

Copy to:

1. The Nodal Officer, NMHS-PMU, National Mission on Himalayan Studies (NMHS), G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand-263643

Annexure-VI

Details, Declaration and Refund of Any Unspent Balance

Refund of unspent balance of amount ₹5,17,264 (Rupees Five Lakhs and Seventeen Thousand and Sixty Four only) has been transferred through RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Bank A/c Details as follows:

Name of NMHS A/c	: NMHS GIA General
Bank Name & Branch	:Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code	: CBIN0281528
Account No.	: 3530505520 (Saving A/c)

(PROJECT INVESTIGATOR)
(Signed and Stamped)

1.12.2022

(FINANCE OFFICER)
(Signed and Stamped)

(HEAD OF THE INSTITUTION)
(Signed and Stamped)