MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

SDG 13

SUSTAINABLE DEVELOPMENT GOALS

REPORT 2023

13 CLIMATE ACTION

MANIPAL UNIVERSITY
JAIPUR

MUJ is committed to climate action and policies that minimize carbon emissions in conserving energy. The university ensures the integration of climate change education into its curricula and encourages their participation in environmental initiatives. As it helps increase research on climate change solutions, MUJ, in turn, contributes to global efforts in the fight against climate-related issues, as well as to raise awareness on sustainable practices.

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1. Academics
2. Research
3. Events
4. Collaborations

ACADEMICS

MANIPAL UNIVERSITY
JAIPUR

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF ENGINEERING

SAMM

DEPARTMENT OF MECHATRONICS ENGINEERING

Expert talk on "Advancement in Robotics and Sustainable Application"

Date of Event (07th November 2023)

SUSTAINABLE DEVELOPMENT GOALS

DEPARTMENT OF MECHATRONICS ENGINEERING ★MUJ★

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8. Schedule of the Event
9. Attendance of the Event
10. Feedback of the event

1. Introduction of the Event

The Department of Mechatronics Engineering, Manipal University Jaipur organized a organising an online Expert talk on "Advancement in Robotics and sustainable application" on 07th November 2023. This workshop will acquaint research scholars, students, of FOE on recent advancement in Robotics application and probable career opportunities in same.

2. Objective of the Event

To create awareness among research scholars, students, on recent advancements in Robotics and its sustainable applications in the Western world. The event also targeted to provide information on opportunities to pursue career and higher study in this field.

3. Beneficiaries of the Event

Students and Research Scholars of MUJ

4. Details of the Guests

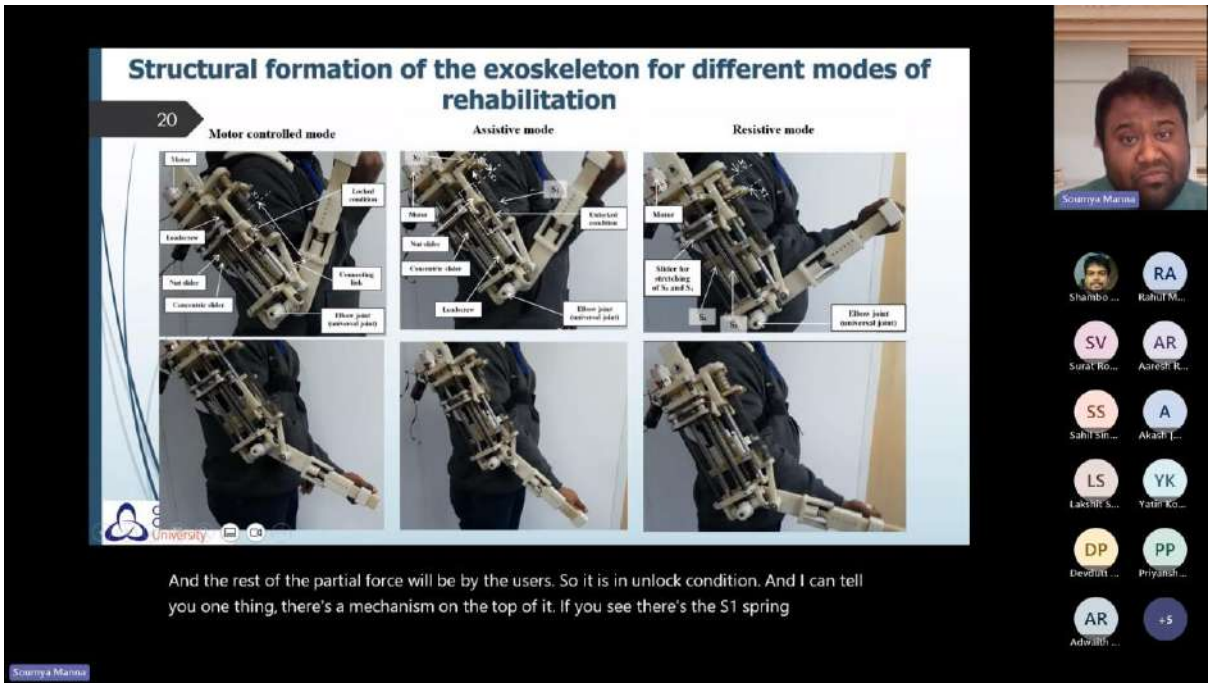
The guest speaker, Dr Soumya Kanti Manna, has received his PhD in Medical Robotics and his research interest lies primarily in the areas of designing medical equipment such as wearable exoskeletons for assistance and rehabilitation, sensor deployment for gait analysis, and IoT-based biomedical applications. So far, he has published more than 35 research papers in reputed conferences and journals, working as a guest editor and reviewer in top journals and conferences.

5. Brief Description of the event

Dr Soumya Kanti Manna, provided a very insightful talk on wearable exoskeletons for assistance and rehabilitation, sensor deployment for gait analysis, and IoT-based biomedical applications. It was conducted in online mode in Microsoft Team. The event was started with an introductory note by the organisers, before handing out for the expert talk to the guest. The talk included topics on wearable exo-skeletons, most recent and popular research topic on bio-medical robotics and IoT applications on this area. Students from all departments of FOE, MUJ joined the session. The session concluded with valedictory note by HOD, Mechatronics.

DEPARTMENT OF MECHATRONICS ENGINEERING ★MUJ★

6. Photographs



7. Brochure or creative of the event

8. Schedule of the event

7th November 2023 from 2:00 - 3:30 pm in online mode.

Recording link: **https://mujcampus-my.sharepoint.com/:v:/g/personal/shamboroy_choudhury_jaipur_manipal_edu/ESIQNPI8skRGI8ZxNc9VEeoBepKdR_ByzcZV88gmas8sdQ?referrer=Teams.TEAMS-ELECTRON&referrerScenario=MeetingChicletGetLink.view.view**

9. Attendance of the Event

Total attendee:- 40

Sl No	Name	Role
1	Shambo Roy Chowdhury [MU - Jaipur]	Organizer
2	Dr. Mrinmoy Misra [MU - Jaipur]	Organizer
3	Dr. Shahbaz Ahmed Siddiqui [MU - Jaipur]	Organizer
4	Soumya Manna	Presenter
5	Divyansh Nagar [Mechatronics - 2022]	Attendee
6	Rahul Marion Anthony[Mechatronics - 2020]	Attendee
7	Surat Rohit Venkat [Mechatronics - 2020]	Attendee

8	Yatin Kohli [Mechatronics - 2020]	Attendee
9	Vanshit Aggarwal [Mechatronics Engineering - 2020]	Attendee
10	Lakshit Sharma [Mechanical - 2020]	Attendee
11	Himanish Bhattacharya [Mechatronics- 2020]	Attendee
12	[BTECH-036-2023-24] HARSHIT JAWA	Attendee
13	Aaresh Rajawat[Mechatronics - 2020]	Attendee
14	[BTECH-031-2023-24] VIBHAV CHANDSI	Attendee
15	[BTECH-005-2023-24] MANUSHREE BARTARIA	Attendee
16	[BTECH-005-2023-24] Harshil Bhardwaj	Attendee
17	Raj Paresh Shah[Mechatronics - 2020]	Attendee
18	[BTECH-007-2023-24] MAYANK GOYAL	Attendee
19	[BTECH-035-2023-24] MEEMANSHA SRIVASTAVA	Attendee
20	[BTECH-006-2023-24] ZIYA PARWEEN	Attendee
21	Harsh Gupta	Attendee
22	Ritik Kumar [Mechatronics - 2021]	Attendee
23	[BTECH-007-2023-24] harshita jain	Attendee
24	Dhruv Desai [Mechatronics - 2020]	Attendee
25	[BTECH-035-2023-24] HEMKANT KUMARRAY	Attendee
26	[BTECH-035-2023-24] MANVIK TALWAR	Attendee
27	Vinayak Kushwah [Mechatronics - 2022]	Attendee
28	Abhay Aaron Apte [MECHATRONICS - 2022]	Attendee
29	[BTECH-031-2023-24] YASH MITTAL	Attendee
30	Akash [Mechatronics - 2022]	Attendee
31	[BTECH-035-2023-24] HARSHIT GOYAL	Attendee
32	Sahil Singh [Automobile - 2020]	Attendee
33	Shashank M K [Mechanical - 2022]	Attendee
34	Priyanshu D. Parikh[Mechatronics - 2020]	Attendee
35	Udit Vohra [MECHATRONICS - 2021]	Attendee
36	Devdutt Patel [MECHATRONICS - 2022]	Attendee
37	Adwaith Ramesh [MECHATRONICS - 2022]	Attendee
38	Moti Kumar Jha [MU - Jaipur]	Attendee
39	Karan Jalwani	Attendee
40	Gunn Verma [MECHATRONICS - 2022]	Attendee

41	Karan Jalwani	Attendee
42	Rahul Acharya[Mechatronics - 2020]	Attendee

International Attendee:

1. Pranay Mahindrakar — University of Bath (UK)
2. Krishanu Agarwal — Georgia Institute of Technology (USA)

10. Feedback Report

Students of FOE, MUJ participated and gained knowledge on opportunities to pursue career and higher study in the field of wearable exoskeletons for assistance and rehabilitation, sensor deployment for gait analysis, and IoT-based biomedical applications.

DIRECTORATE OF STUDENTS' WELFARE

Workshop on

MENSTRUAL HEALTH AND HYGIENE

ENVIRO CLUB

Department of Biosciences

OFFLINE EVENT

Date of Event (2nd November 2023)

(11:30 AM to 2:00 PM)

(AB1 Room No.105)

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- **Introduction of the Event**

ENVIRO CLUB organized a '**MENSTRUAL HYGIENE AND HEALTH'** on the 2nd of November 2023. To debunk all the myths and raise awareness for proper hygiene and proper use of sanitary pads.

This event is arranged to break the stigma and form a supporting community.
This event is a collaboration with "Saukhyam" an organization for reusable pads and an initiative started by Sri Mata Amritanandamayi Devi.

- **Objectives of the Event**

- To raise awareness about menstrual hygiene, debunk myths, and promote the use of sustainable sanitary products like reusable pads. It's also aimed at creating a supportive community where these topics can be openly discussed. A truly commendable initiative

- Primarily, it aims to debunk myths surrounding menstrual hygiene, promoting proper sanitary practices. It also seeks to break societal stigmas and create a supportive community where these topics can be discussed openly. Lastly, by partnering with "Saukhyam", the event promotes the use of reusable pads, contributing to environmental sustainability. It's an all-round initiative for health, awareness, and environment.

- To empower people with knowledge and understanding about menstrual hygiene, which is often misunderstood or misrepresented in society. By providing factual and practical information, the event could help to change attitudes and behaviors, leading to better health outcomes and greater equality. And let's not forget the environmental aspect - by promoting the use of reusable pads, the event is also contributing to the fight against plastic waste and promoting sustainability.

- **Beneficiaries of the Event**

- MUJ students and Staff

- **Brief Description of the event**

On the 2nd of November, 2023, the Enviro Club organized a comprehensive workshop on Menstrual Health and Hygiene at Venue AB1, 105. The event featured various segments, including the formal welcome of esteemed guests and attendees, followed by the introduction of Saukhyam and its representative, Ms. Divya Rai.

During her presentation, Ms. Rai enlightened the audience about the paramount importance of menstrual health. She provided insights into Saukhyam's unique approach to manufacturing eco-friendly and biodegradable menstrual pads, utilizing banana fiber. Emphasizing their commitment to sustainability, Ms. Rai highlighted the absence of harmful chemicals in Saukhyam pads.

Furthermore, Ms. Rai elucidated the intricate process involved in crafting these pads and offered detailed instructions on their correct usage. The informative session aimed at raising awareness about sustainable menstrual products proved to be educative for both staff members and students in attendance.

Taking the initiative a step further, Ms. Divya Rai, in collaboration with Dr. Monika Sogani, the faculty coordinator of Enviro Club, decided to randomly distribute samples of Saukhyam pads

among the audience. This strategic move aimed to encourage firsthand experiences and gather genuine feedback from the participants, fostering a dialogue on the efficacy of sustainable sanitary options.

In summary, the Menstrual Health and Hygiene workshop hosted by the Enviro Club served as a platform for introducing Saukhyam and promoting awareness about eco-friendly menstrual pads. The event not only contributed to the dissemination of crucial information but also allowed for practical engagement through the distribution of samples, benefiting both the academic community and staff members alike.

- **Photographs**

- **Brochure or Creative of the Event**

MANIPAL UNIVERSITY JAIPUR

ENVIRO CLUB

Department of Biosciences

in collaboration with

Department of ECE

and

Atal Incubation Center MUJ,

DIRECTORATE OF STUDENT WELFARE (DSW)

Presents

Awareness Workshop on

Menstrual Health & Hygiene

Speaker : Ms. Divya Rai

(Director, Outreach Programs Saukhyam Reusable Pads.)

Date : 2nd November 2023
Time : 11:30 AM Onwards
Venue : AB1, 105

Convenor :

Dr. Monika Sogani
(Sr. Associate Professor, Department of Biosciences)
(Faculty Coordinator, Enviro club, MUJ)

Dr. Deepika Bansal
(Assistant Professor Department of ECE)

Saukhyam
Reusable Pads

NOV 2
@
11:30 AM

BETTER FOR OUR SEAS, TREES,
OUR BODIES AND OUR WALLETS

DITCHING DISPOSABLES

BEAUTIFUL

NATURAL

BANANA FIBER
SUPER ABSORBENT

ESSENTIAL

AWARDED BY
NITI AAYOG

FOR A MORE WHOLESOME
PERIOD EXPERIENCE

Organiser: **ENVIRO CLUB**

WITH REUSABLE MENSTRUAL PADS

- **WE COMBAT** CLIMATE CHANGE
- **SAFEGUARD OUR** HEALTH
- **SAVE NEARLY** HALF A LAKH OF RUPEES !

To learn more, we invite you to attend our awareness workshop

saukhyampads.org | +91 8971042444 | info@saukhyampads.org

Contact: (Enviro Club) 7807866869

- **Schedule of the event**

2nd November 2023 from 11:30 AM onwards

- **Attendance of the event:**

S No.	Name	Reg. no	Course	Year
1	vanshita	221014003	msc biotech	2
2	bhoomika	221014010	msc biotech	2
3	aditi	221014008	msc biotech	2
4	nandini	211003001	bsc hons microbio	3
5	mrunal	211003007	bcs hons microbio	3
6	ayush	211003012	bsc hons microbio	3
7	durgesh	229302418	btech cse iot	2
8	ankit	221014016	msc biotech	2
9	pranav	229303145	btech cse iot	2
10	rijul	229311015	btech cse iot	2
11	arohi	221014006	msc biotech	2
12	priti	221014004	msc biotech	2
13	tribhuvan	221015077	bca	2
14	megha	23fa10bsp00017	bsc hons psychology	1
15	ayushi	23FM10BBA00184	BBA	1
16	SYLVIA	211003009	BSC microbiology	3
17	Bhumi	23FM10BBA00210	bba	1
18	Simran wadhwani	23FM10BBA00201	BBA	1
19	kusum	23fm20MBA0029	MBA	1
20	NEHA SINGH	23FM20MBA00035	MBA	1
21	Anushka Kesarwani	220903014	bcom hons	2
22	Nidhi Mehata	220903068	bcom hons	2

and all female MIS staff of MUJ (Approx 100).

Assistant Director, DSW

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

MANIPAL UNIVERSITY
JAIPUR

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF ENGINEERING

SCHOOL OF COMPUTER AND COMMUNICATION ENGINEERING

DEPARTMENT OF COMPUTER AND COMMUNICATION ENGINEERING

IN ASSOCIATION WITH

IEEE RAJASTHAN SUB SECTION,

IEEE SENSORS COUNCIL MANIPAL UNIV. JAIPUR STUDENT BRANCH CHAPTER

AND

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

IEEE RAJSTHAN SUB SECTION SPONSORED INVITED TALK

ON

"NANOSHEET-FORKSHEET CO-INTEGRATED N-P TECHNOLOGY FOR EMERGING TECHNOLOGY"

Type of Event (INVITED TALK / LECTURE)

Date of Event (9th JUNE 2023)

Content of Report

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3. Beneficiaries of the Event
4. Details of the Guests
5. Brief Description of the event
6. Geo-tagged Photographs
7. Brochure or creative of the event
8. Schedule of the Event

1. Introduction of the Event

IEEE Rajasthan Subsection sponsored invited talk on "Nanosheet – Forksheet Co-Integrated N-P Technology for emerging technology was jointly organised by IEEE Rajasthan Subsection in association with Student Branch, IEEE Sensor Council Manipal University Jaipur and Malaviya National Institute of Technology, Jaipur on 9th June 2023 from 4:00 PM onwards at Committee Room, Department of Electronics and Communication Engineering, Malaviya National Institute of Technology. The event was also partly sponsored by Manipal University Jaipur. The keynote speaker is distinguished lecturer of IEEE and had delivered a lecture on the topic "**NANOSHEET-FORKSHEET CO-INTEGRATED N-P TECHNOLOGY FOR EMERGING TECHNOLOGY"** which is an emerging research area in novel nano-electronic devices and sensors design as well as fabrication. Many students and faculty members from Manipal University Jaipur had joined the event in online mode.

2. Objective of the Event

- The primary focus of the event was to shed light on the intricate details of Nanosheet - Fork sheet Co-Integrated N-P Technology and its implications in the rapidly evolving world of emerging technologies.

3. Beneficiaries of the Event:

The beneficiaries of the event would be the students and faculty members doing research in the domain of new emerging nano electronic technologies.

4. Details of the Guests

Prof. Sudeb Dasgupta,
MIEEE, Fellow DAAD, Fellow IUSSTF, Fellow Erasmus Mundus,
Department of Electronics and Communication Engineering,
Indian Institute of Technology, Roorkee
Email: sudeb.dasgupta@ece.iitr.ac.in

5. Brief Description of the event

Inaugural Address: The event began with an inaugural by a distinguished expert in the field. The speaker emphasized the importance of innovative technologies like Nanosheet - Fork sheet Co-Integrated N-P Technology in shaping the future of various industries.

Technical Session: The heart of the event comprised a comprehensive technical session . The session delved into the nuances of Nanosheet - Forksheet Co-Integrated N-P Technology, highlighting its principles, advantages, and potential applications across domains such as electronics, materials science, and energy.

Interactive Discussion: Following the technical session, a lively and engaging discussion took place. Participants had the opportunity to pose questions, share their insights, and engage in thought-provoking discussions with the speaker. This interaction enhanced the overall learning experience and provided valuable insights into the practical aspects of implementing this technology.

The event yielded several positive outcomes, including:

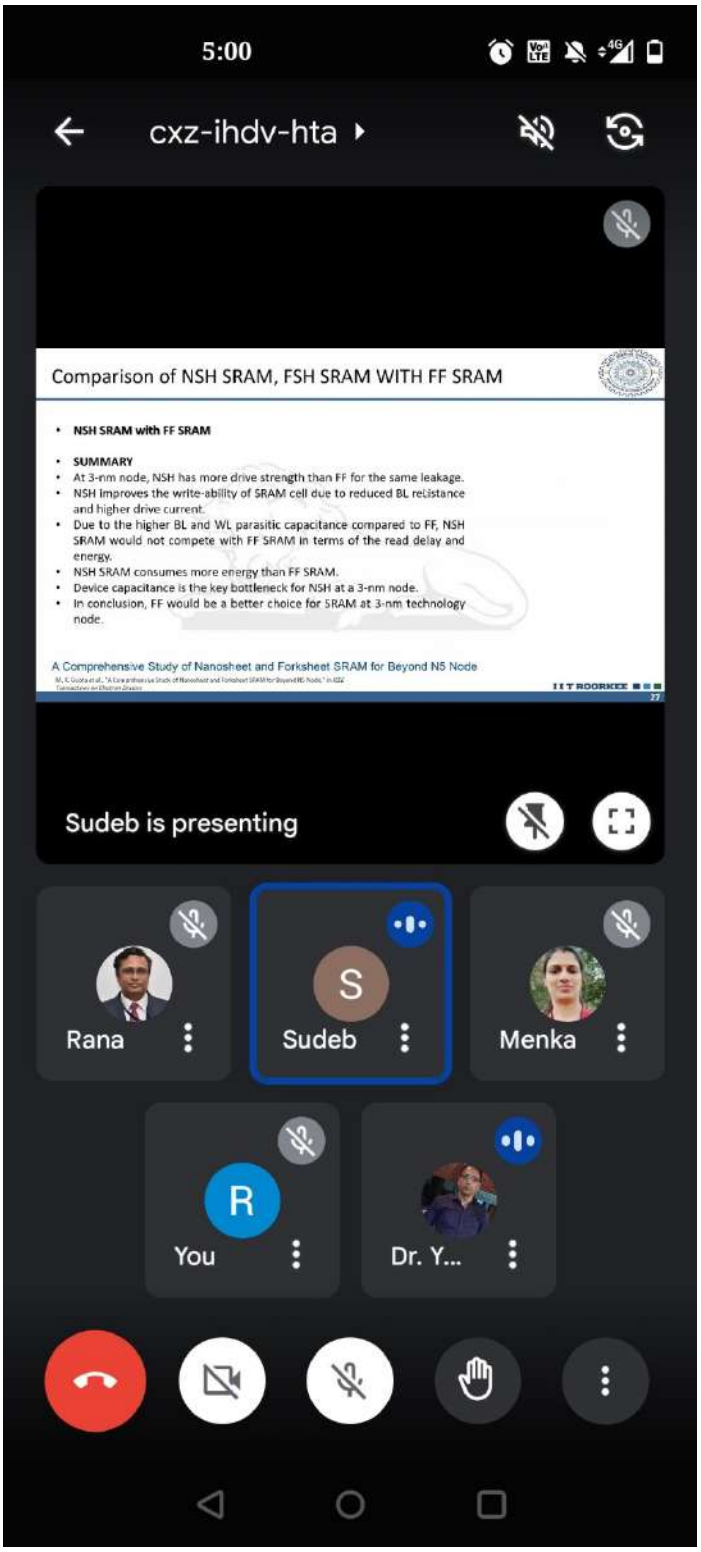
- **Enhanced Knowledge:** Participants gained a deeper understanding of Nanosheet - Forksheet Co-Integrated N-P Technology and its potential applications, contributing to their technical knowledge and awareness.
- **Networking Opportunities:** The event provided a platform for participants to connect with fellow enthusiasts, experts, and professionals in the field, fostering valuable networking relationships.
- **Inspiration:** The event inspired participants to explore innovative technologies and consider their roles in shaping the future of emerging technologies.

6. Photographs

Picture 1: Prof. Sudeb Dasgupta giving the talk

Picture 2: Participants listening to the lecture.

Picture 3: Group Photograph of the Invited Speaker with organizers and participants.



Picture 4: Online lecture screenshot

7. Brochure or creative of the event

8. Schedule of the event

Event	Venue / Online Link of Event	Date, Time
Invited Talk	**Venue:** Committee Room, Dept. of ECE, Malaviya National Institute of Technology, Jaipur **Online Link:** https://meet.google.com/cxz-ihdv-hta	9th June 2023, 4:00 PM onwards

Head
Department of CCE
Manipal University Jaipur

Seal and Signature of Head with date

MANIPAL UNIVERSITY JAIPUR

FACULTY OF DESIGN

School of Design & Art

Department of Fashion Design

Interactive Talk

24th Nov 2023

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1. **Introduction of the Event**

   The Department of Fashion Design at Manipal University Jaipur organized a masterclass on "design Process." The lecture was conducted on 3rd Nov 2023, from 2:30 pm to 3:30 pm, via online mode at Manipal University Jaipur. The purpose of the event was to help students and academicians gain a better understanding of the design process.

2. **Objective of the Event**

   The event aimed to provide participants with an in-depth understanding of the circular economy and sustainable practices, leveraging Prof. Charter's extensive experience and expertise. The focus was on how these practices can be implemented across various sectors, with a special emphasis on fashion design. The interactive talk sought to inspire and educate students and researchers on integrating sustainable practices into their work and aligning them with the Sustainable Development Goals (SDGs), particularly focusing on SDG 8: Decent Work and Economic Growth, and SDG 11: Sustainable Cities and Communities. This session was envisioned as an engaging platform for participants to delve into the significance of circular economy principles and their practical application in the realm of fashion design, promoting economic growth through sustainable industrial practices and fostering urban development that respects the limits of natural resources.

3. **Beneficiaries of the Event:**

   Students of Faculty of Design, Manipal University Jaipur

4. **Details of the Guest:**

   Prof. Martin Charter is a renowned sustainability expert with over three decades of experience in director-level roles across multiple industries, including consultancy, leisure, publishing, training, events, and academia. He has a substantial background in strategy, research, marketing, and eco-innovation. His leadership and innovation in sustainable business practices have been widely recognized.

   Key Achievements:

   Director of The Centre for Sustainable Design: For 28 years, Prof. Charter founded and directed this internationally acclaimed center, focusing on product sustainability and sustainable innovation. Under his leadership, the center generated significant income through research, training, consultancy, and events.

   Significant European Commission Involvement: Prof. Charter has actively led and managed numerous EC-funded research and knowledge transfer projects, significantly contributing to sustainability efforts in Europe and Asia.

   Global Training Programs: He has conducted worldwide training for large companies and SMEs, covering essential topics like sustainability, business, innovation, design, and marketing.

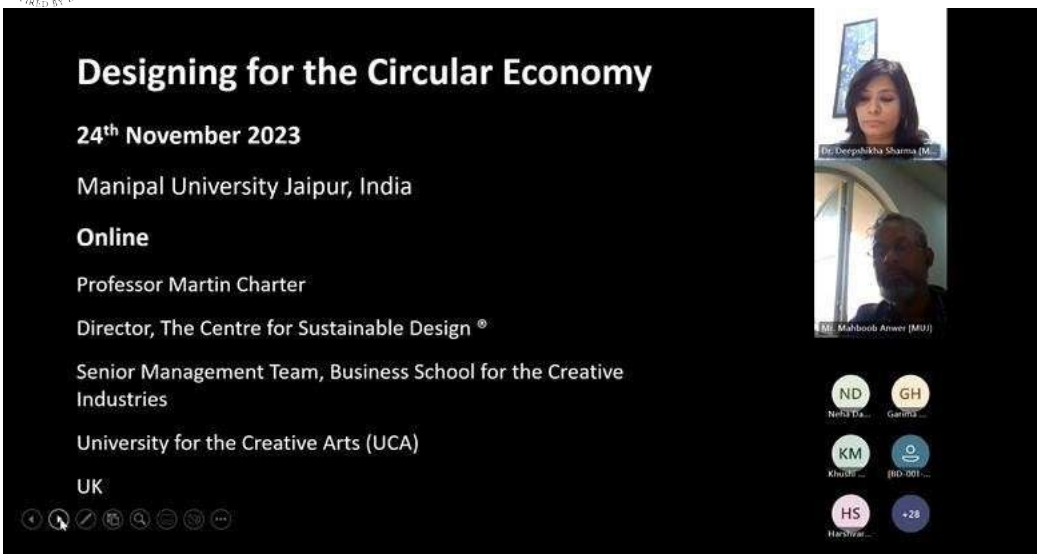
   Expertise in European Manufacturing and Eco-Innovation: As a member of various European Commission expert groups, he has contributed to the development of standards and practices in textiles, metals, and eco-innovation.

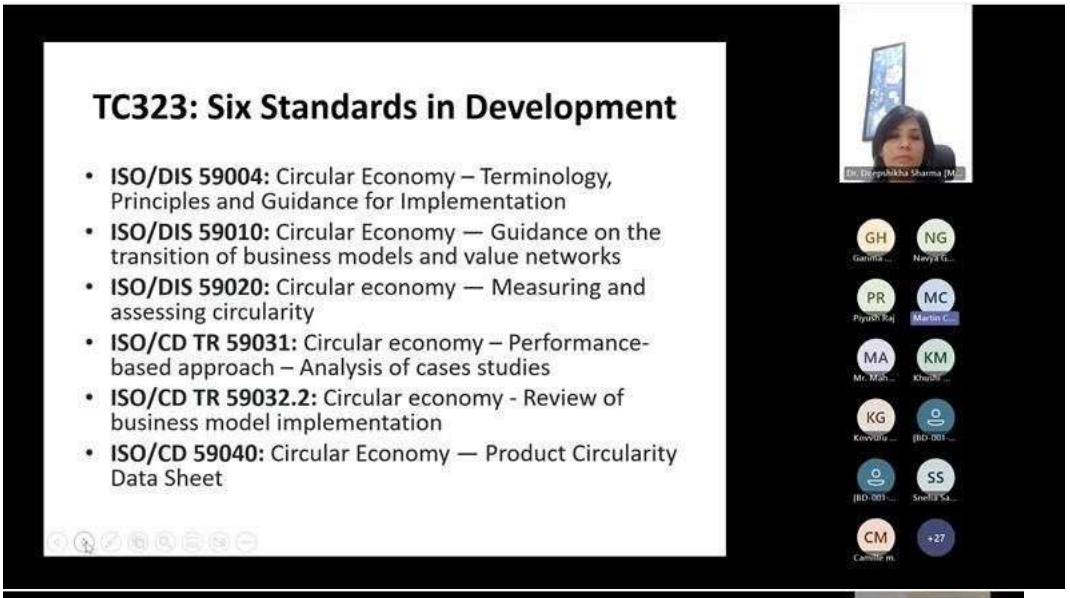
Leadership at UCA: His role as Chair of the UCA Environmental & Social Sustainability Working Group highlights his commitment to integrating sustainability into education and academia.

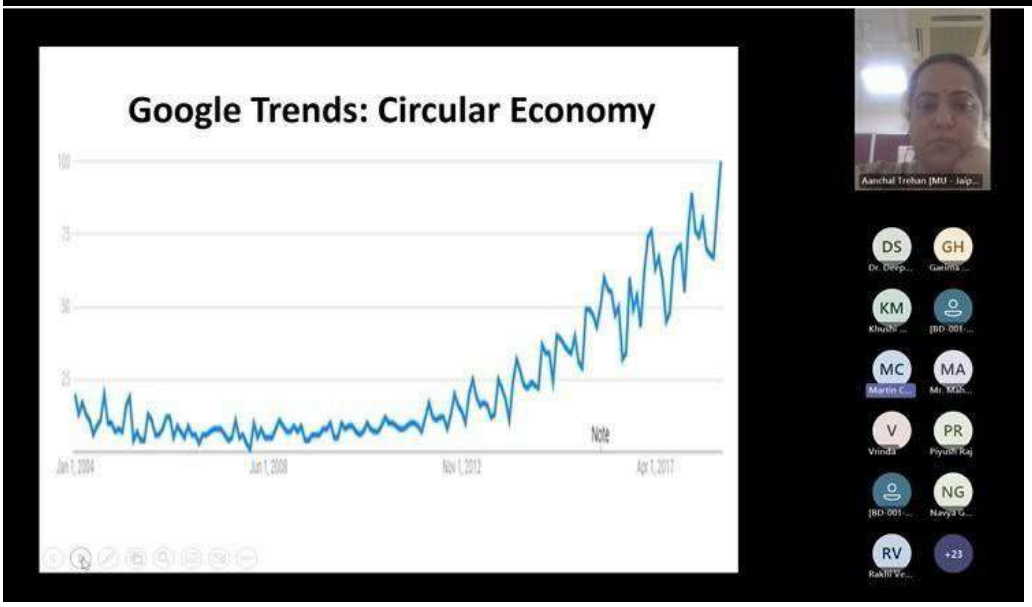
5. **Brief Description of the event: -**

The interactive talk on "Circular Economy (Sustainable practices)" at Manipal University Jaipur was a comprehensive session that aimed to explore and elucidate the principles of circular economy within the context of fashion design. Led by Prof. Martin Charter, a luminary in sustainability, the event delved into how sustainable practices can be seamlessly integrated into various sectors. It emphasized the alignment of these practices with the Sustainable Development Goals (SDGs), particularly focusing on SDG 8: Decent Work and Economic Growth, and SDG 11: Sustainable Cities and Communities. The talk aimed to foster an understanding among students and research scholars of the critical role circular economy principles play in contemporary design and in promoting sustainable economic and urban development. The session was designed to be engaging, encouraging active participation and discourse, and offering attendees a platform to contribute to and expand their knowledge in sustainable design.

6. **Photographs of the event**


Designing for the Circular Economy
24th November 2023
Manipal University Jaipur, India
Online
Professor Martin Charter
Director, The Centre for Sustainable Design ®
Senior Management Team, Business School for the Creative Industries
University for the Creative Arts (UCA)
UK


TC323: Six Standards in Development
ISO/DIS 59004: Circular Economy – Terminology, Principles and Guidance for Implementation
ISO/DIS 59010: Circular Economy — Guidance on the transition of business models and value networks
ISO/DIS 59020: Circular economy — Measuring and assessing circularity
ISO/CD TR 59031: Circular economy – Performance-based approach – Analysis of cases studies
ISO/CD TR 59032.2: Circular economy - Review of business model implementation
ISO/CD 59040: Circular Economy — Product Circularity Data Sheet


Google Trends: Circular Economy
Note

7. Schedule of the event

The lecture was conducted on 24th Nov 23, from 3:00 pm to 4:00 pm via online mode at Manipal University Jaipur.

8. Total attendee of the Event – 41

S.No.	Full Name
1	Aanchal Trehan [MU - Jaipur]
2	Dr. Deepshikha Sharma [MU - Jaipur]
3	Mr. Mahboob Anwer [MUJ]
4	Indrajeet Kumar [MU - Jaipur]
5	Dr. Sampath Kumar Padmanabha Jinka [MU - Jaipur]
6	Harshwardhan Soni [MU - Jaipur]
7	Prof. Carla Costa Pereira
8	Ms camiile Moco
9	Harshvardhan Singh
10	Vrinda
11	Neha Dagdi
12	Martin Charter
13	Vidisha Bajaj
14	Sakshi Agrawal
15	Simran Parag Patil
16	Drishti Tiwari
17	Rakhi Verma
18	Jagrati Jain
19	Samya Gupta
20	Piyush Raj
21	Tamanna Gracy Singh
22	Navya Gupta
23	Garima Hotwani
24	Khushi Mehta
25	Shruti Verma
26	Krittika
27	Adrija Rathore
28	Shailja

29	Sneha Sarkar
30	Kovvuru Geetika
31	Camille M.
32	Priya Lodhi
34	Nishtha
35	Khushi Porwal
36	Anu
37	Rajnish Kumar
38	Anushka
39	Harshwardhan Soni
40	Kavya Kalra
41	Shubhi Tambi

Dr. Deepshikha Sharma

Department of Fashion Design

School of Design & Art

MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

Department of Interior Design

FACULTY OF DESIGN

Make & Take

Kokedama

Hands-on Workshop

22/11/2023

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10. Link of the event

1. Introduction of the Event

The Department of Interior Design, Faculty of Design at Manipal University Jaipur organized a Kokedama Workshop on 22.11.2023, as a part of the curriculum for 3rd-year B.Des (ID) students. This workshop was conducted under the subject Interior Landscape (ID3105) to provide students with a practical, hands-on experience in the art of preparing Kokedamas. Along with 3rd year B. Des students, this workshop is open for all Manipal University Jaipur students (Diploma, Undergraduate and Postgraduate), Research Scholars, Academicians, Faculty Housing Women, And Industry Professionals with fees of Rs 300/- that included all the materials.

An introduction and demonstration to Kokedama was given by Ms. Geeta Ahluwalia, General Secretary, Kitchen Garden Association, Jaipur. Kitchen Garden Association is an all women lead non-profit organisation in Jaipur. Ar. Sneh Singh (HoD Interior Design) along with Ar. Megha Prabhu K (Asst. Professor, Interior Design) conducted a hands-on 'Make & Take' Kokedama Workshop.

2. Objective of the Event

- Provide 3rd-year B. Des (ID) students with a hands-on experience in the preparation of Kokedamas.
- Enhance the understanding of interior landscaping principles among participants and foster practical skills in crafting Kokedamas, focusing on plant selection, soil composition, and wrapping techniques.
- Facilitate knowledge exchange and collaboration among participants from diverse academic backgrounds, including students, research scholars, academicians, and industry professionals.
- Encourage creativity and innovation in Interior Design through the exploration of Japanese moss ball planters.
- Provide a platform for participants to engage in a Q&A session, allowing for a deeper understanding of the art of Kokedama.
- Create a supportive and inclusive learning environment for all attendees, fostering a sense of community and collaboration within Manipal University Jaipur.

3. Beneficiaries of the Event

The workshop was open to a diverse audience, including 3rd-year B.Des(ID) students, students from other programs (Diploma, Undergraduate, and Postgraduate) at Manipal University Jaipur, research scholars, academicians, Faculty Housing Women, and industry professionals. The inclusive nature of the workshop aimed to foster collaboration and knowledge exchange among participants.

4. Details of the Guests

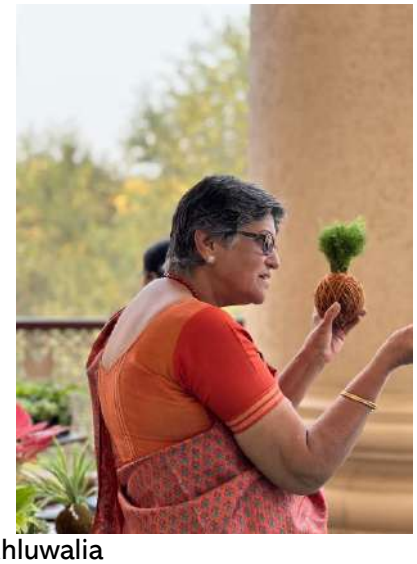
The honoured guest for the event was Ms. Geeta Ahluwalia, the Secretary of the Kitchen Garden Association Jaipur. Kitchen Garden Association is an all women lead non-profit organisation in Jaipur. Ms. Ahuwalia's expertise in the field brought a valuable perspective to the workshop, and her presence added significant value to the overall learning experience for the participants.

5. Brief Description of the event

The Kokedama workshop provided a unique opportunity for participants to explore the creative and technical aspects of crafting Kokedamas, which are Japanese moss ball planters. The event kicked off with a warm welcome to all attendees, followed by an insightful introduction to the art of Kokedama and its relevance in interior design.

Participants were guided through the step-by-step process of creating their own Kokedamas, emphasizing the selection of suitable plants, soil composition, and wrapping techniques. Ms. Ahuwalia shared her expertise and provided practical tips, enriching the learning experience for everyone involved.

6. Photographs of the Event



Introduction and Demonstration given by Expert, Ms. Geeta Ahluwalia

Demonstration of Kokedama given by Expert, Ms. Geeta Ahluwalia

Participants showcasing their works

7. Poster of the event

8. Schedule of the event

'Make & Take' Kokedama Workshop 22 November 2023, Wednesday	
Porch Area, 1st Floor, Administration Building, MUJ	
Time	**Event**
09:30 am	Registration and Reporting
10:30 am	Welcome address by Ar. Megha Prabhu Karkala Introduction of the Guest Adress by Dean, Prof. (Dr.) Madhura Yadav, Dean, FoD
10:45 am	Expert Lecture and Introduction to Kokedama by Ms. Geeta Ahuwalia
11:00 am	Practical Session: Crafting Kokedamas
11:30 am	Making Kokedamas by students
12:45 pm	Completion of Kokedamas and Q&A Session
01:00 pm	Felicitation of Ms. Geeta Ahuwalia and Closing Remarks
01:15 pm	Group Photographs and Exhibition of Students works

9. Attendance of the Event

Sl.No	Participate Name	Participant	Deparment	Registration No.
1	Kashish Kriplani	Student	B.Des (Interior Design)	210606041
2	Kartik Totla	Student	B.Des (Interior Design)	210606011
3	Aakash Singh	Student	B.Des (Interior Design)	210501007
4	Garima Vijaycharan	Student	B.Des (Interior Design)	210606021
5	Kumari Anjali	Student	B.Des (Interior Design)	210606008
6	Himanshi Sharma	Student	B.Des (Interior Design)	210606028
7	Esha Giri	Student	B.Des (Interior Design)	210606031
8	Anisha Chopra	Student	B.Des (Interior Design)	210606020
9	Rutu Shah	Student	B.Des (Interior Design)	210606007
10	Anushka Rai	Student	B.Des (Interior Design)	210606019
11	Rishika	Student	B.Des (Interior Design)	210606029
12	Paridhi Verma	Student	B.Des (Interior Design)	210606017
13	Naman	Student	B.Des (Interior Design)	210606013
14	Diya Ramchandani	Student	B.Des (Interior Design)	210606039
15	Krishangee Goyal	Student	B.Des (Interior Design)	210606026
16	Avinash Yadav	Student	B.Des (Interior Design)	210606047
17	Himanshi Yadav	Student	B.Des (Interior Design)	210606014
18	Hridyanshi Vyas	Student	B.Des (Interior Design)	210606018
19	Khushi Bhargava	Student	B.Des (Interior Design)	210606010
20	Madhu Tanwar	Student	B.Des (Interior Design)	210606027
21	Riddhi Agarwal	Student	B.Des (Interior Design)	210606038
22	Michelle Earnest	Student	B.Des (Interior Design)	210606043

23	Pooja Jain	Student	B.Des (Interior Design)	23fd10bid00020
24	Shreshtha Gaur	Student	B.Des (Interior Design)	210606012
25	Geetika Gupta	Student	B.Des (Interior Design)	210606037
26	Manya Agarwal	Student	B.Des (Interior Design)	210606015
27	Riya	Student	B.Des (Interior Design)	210606035
28	Ananya Thakan	Student	B.Des (Interior Design)	210606006
29	Devanshi Jain	Student	B.Des (Interior Design)	210606046
30	Drishti Sharma	Student	B.Des (Interior Design)	210606045
31	Sejal Sharma	Student	B.Des (Interior Design)	210606023
32	Samarth Gandhi	Student	B.Des (Interior Design)	210606003
33	Saija Tanya	Student	B.Des (Interior Design)	210606044
34	Garvit Garg	Student	B.Des (Interior Design)	210606001
35	Shruti Dubey	Student	B.Des (Interior Design)	210606022
36	Keshav Katta	Student	B.Des (Interior Design)	210606005
37	Grishma Korjani	Student	B.Des (Interior Design)	210606016
38	Shweta Sharma	Non-Teaching Staff	Non- Teaching Staff	MUJ1134
39	Megha Prabhu Karkala	Assistant Professor	Faculty of Design	MUJ1434
40	Smriti Saraswat	Assistant Professor	Faculty of Design	MUJ1248
41	Dr. Shilpi Gupta	Assistant Professor	Department of Economics	MUJ0403
42	Malini G Prabhu	Faculty Housing Member	Faculty Housing Member	NA
43	Rajendar Kumar	Non-Teaching Staff	GSA	MUJ1300
44	Reetika Choudary	Non-Teaching Staff	Admission Department	MUJ1406
45	Priyanka Samarth	Non-Teaching Staff	Admission Department	MUJ1408
46	Panchami Sharma	Non-Teaching Staff	HR Department	MUJ11002438
47	Kusuma Jinka	Faculty Housing Member	Faculty Housing Member	NA
48	Madan	Non-Teaching Staff	GSA	
49	Gopal	Non-Teaching Staff	GSA	
50	Kush Jee Kamal	Assistant Professor	Faculty of Design	MUJ1714
51	Man Mohan Mehta	Non-Teaching Staff	Admission Department	MUJ0170

Manipal University Jaipur
Department of Interior Design I FOD
II Year III Semester - ID3105-Interior Landscape
KOKEDAMA WORKSHOP - 22.11.2023

Sl. No.	ROLL. No.	NAME	SIGN
1	210606001	GARVIT GARG	
2	210606003	SAMARTH GANDHI	
3	210606004	VISHVA SAMIRBHAI DAVE	ABSENT
6	210606005	KESHAV KATTA	
5	210606006	ANANYA THAKAN	
6	210606007	RUTU DILIP KUMAR SHAH	
7	210606008	KUMARI ANJALI	
8	210606010	KHUSHI BHARGAVA	
9	210606011	KARTIK TOTLA	
10	210606012	SHRESHTHA GAUR	
11	210606013	NAMAN HODKASIA	ABSENT
12	210606014	HIMANSHI YADAV	
13	210606015	MANYA AGARWAL	
14	210606016	GRISHMA KORJANI	
15	210606017	PARIDHI VERMA	
16	210606018	HRIDYANSHI VIRESH VYAS	
17	210606019	ANUSHKA RAI	
18	210606020	ANISHA CHOPRA	
19	210606021	GARIMA VIJAY CHARAN	
20	210606022	SHRUTI DUBEY	
21	210606023	SEJAL SHARMA	
22	210606026	KRISHANGEE GOYAL	
23	210606027	MADHU TANWAR	
24	210606028	HIMANSHI SHARMA	
25	210606029	RISHIKA	
26	210606031	ESHA GIRI	
27	210606034	KREETI YADAV	ABSENT
28	210606035	RIYA GAUTAM ROY	
29	210606036	HRIDAY SINGH	ABSENT
30	210606037	GEETIKA GUPTA	
31	210606038	RIDDHI AGARWAL	
32	210606039	DIYA RAMCHANDANI	
33	210606041	KASHISH KRIPLANI	
34	210606043	MICHELLE EARNEST	
35	210606044	SAIJA TANYA	
36	210606045	DRISHTI SHARMA	
37	210606046	DEVANSHI JAIN	
38	210606047	AVINASH YADAV	
39	210501007	AKASH	

Manipal University Jaipur
Department of Interior Design
Faculty of Design
KOKEDAMA WORKSHOP - 22.11.2023

Sl. No.	MUJ ID/ Roll No	NAME	Department	SIGN
1	MUJ13005	Rangendra Kumar	G/13/A	
2	MUJ1406	Reetika Choudhary	Admission	
3	MUJ1408	Priyanka Semwal	Admission	
6				
5	MUJ11002438	Pancham Sharma	HR	
6	FH member	Malini G Prabhu	Faculty Housing	Malini Prabhu
7	FH member	Rukuma Jinka	Faculty Housing	
8	MUJ403	Dr. Dilipa Gupta	Economics.	
9		Madan	G&A	
10		Gopal	G&A -	
11	MUJ1134	Shweta Sharma	Senior-Personal Assistant	
12	MUJ1714	Rajesh Jee Kana	JD	
13	MUJ1120	Man Mohan Mulia	Administration	
14				

10. Link of MUJ social media page

LinkedIn: https://www.linkedin.com/feed/update/urn:li:activity:7134914090002526208
Facebook:

- https://www.facebook.com/share/p/veNm8xBHeCEpUkJh/?mibextid=WC7FNe
- https://www.facebook.com/share/p/SESHp8BN95zt4VCP/?mibextid=WC7FNe

Instagram:

- https://www.instagram.com/p/C0JntI-LnvS/?utm_source=ig_web_copy_link&igshid=MzRlODBiNWFlZA==
- https://www.instagram.com/p/C0Jwf4orIKQ/?utm_source=ig_web_copy_link&igshid=MzRlODBiNWFlZA==

Head, Department of Interior Design
SP&D, Faculty of Design
Manipal University Jaipur

RESEARCH

Summary for Manipal University Jaipur 13

Manipal University Jaipur 2021 to 2023

Research performance within SDG 13: Climate Action (2023)

Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024

66

Scholarly Output

1.58

Field-Weighted Citation Impact

16

International Collaboration

2,253

Views Count

508

Citation Count

Collaboration summary within SDG 13: Climate Action (2023)

Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024

International Collaboration

Publications co-authored with Institutions in other countries/regions

Manipal University Jaipur
24.2%

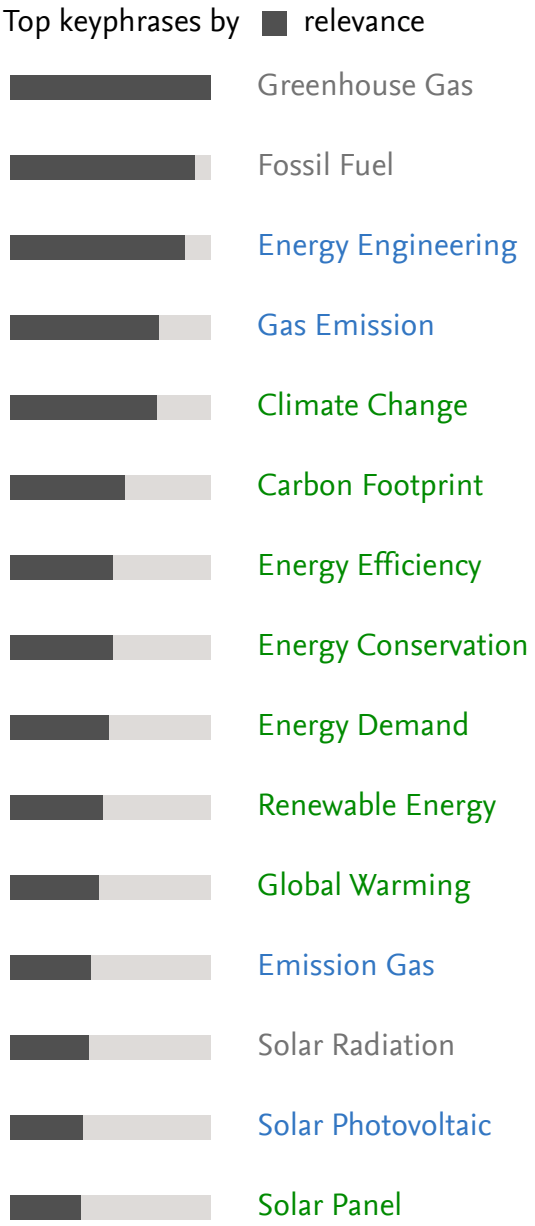
Academic-Corporate Collaboration

Publications with both academic and corporate affiliations

Manipal University Jaipur
0.0%

Top keyphrases within SDG 13: Climate Action (2023)

Entity: Manipal University Jaipur · Within: All subject areas (ASJC) · Year range: 2021 to 2023 · Data source: Scopus, up to 30 Oct 2024



Program/Courses offered in

Program code	Course code	Course name
601	FD1103	FUNDAMENTALS OF DESIGN – I
601	FD1105	MATERIAL EXPLORATION WITH 3D DESIGN – I
601	FD1107	DESIGN THINKING
1004	CY1133	CHEMISTRY LAB-1
1004	BT1150	CYTOLOGY
1004	BT1136	CYTOLOGY LABORATORY
1004	CY1204	MAIN GROUP ELEMENTS-I AND IONIC STRUCTURES
1004	CY1205	STEREOCHEMISTRY AND REACTION MECHANISMS
1004	CY1206	THERMODYNAMICS AND EQUILIBRIUM
1004	CY1233	CHEMISTRY LAB-2
1004	BT1251	MICROBIOLOGY
1004	BT1237	MICROBIOLOGY LABORATORY
1004	BT1252	ENVIRONMENTAL POLLUTION AND HUMAN HEALTH
1004	BT1238	EVIRONMENTAL POLLUTION AND HUMAN HEALTH LABORATORY
1004	CY2104	MAIN GROUP ELEMENTS-II AND INTRODUCTION TO GROUP THEORY
1004	CY2105	HYDROCARBONS AND HALOGEN DERIVATIVES
1004	CY2106	SURFACE, SOLUTIONS, AND MIXTURES
1004	CY2133	CHEMISTRY LAB-3
1004	PY2160	ELECTRONICS
1004	CY2152	FUEL CHEMISTRY
1004	CY2154	POLYMER CHEMISTRY
1004	CY2204	CHEMISTRY OF TRANSITION AND INNER-TRANSITION METALS
1004	CY2205	OXYGEN CONTAINING DERIVATIVES
1004	CY2206	KINETICS AND ELECTROCHEMISTRY
1004	CY2207	NUCLEAR AND ANALYTICAL CHEMISTRY
1004	CY2233	CHEMISTRY LAB-4
1004	CY2243	ENVIRONMENTAL CHEMISTRY
1004	CY2237	ENVIRONMENTAL CHEMISTRY LABORATORY
1004	CY3105	ADVANCED STEREO CHEMISTRY AND HETEROCYCLIC COMPOUNDS
1004	CY3133	CHEMISTRY LAB-5
1004	CY3170	PROJECT
1004	CY3140	BIOINORGANIC CHEMISTRY
1004	CY3107	ORGANOMETALLIC CHEMISTRY
1004	CY3147	CHEMISTRY OF BIOMOLECULES
1004	CY3205	ORGANIC SPECTROSCOPY
1004	CY3206	QUANTUM CHEMISTRY AND ITS APPLICATIONS
1004	CY3233	CHEMISTRY LAB-6
1004	CY3243	INDUSTRIAL CHEMICALS AND ENVIRONMENT
1004	PY3260	MODERN PHYSICS
1004	BT3250	PHYSIOLOGY OF PLANTS
1004	BT3236	PLANT PHYSIOLOGY LABORATORY
1004	CY3244	MATHEMATICS FOR CHEMISTS
9102	CV2101	FLUID MECHANICS
9102	CV2102	BUILDING MATERIALS & CONSTRUCTION TECHNOLOGY
9102	CV2103	SURVEYING
9102	CV2104	STRUCTURAL ANALYSIS

9102	CV2130	MATERIAL TESTING LAB
9102	CV2131	SURVEYING PRACTICE
9102	CV2201	ENGINEERING GEOLOGY
9102	CV2202	WATER SUPPLY ENGINEERING
9102	CV2203	ANALYSIS OF INDETERMINATE STRUCTURES
9102	CV2230	GEOLOGY LAB
9102	CV2231	FLUID MECHANICS LAB
9102	CV2232	BUILDING DRAWING AND DESIGN
9102	CV3101	GEOTECHNICAL ENGINEERING
9102	CV3102	HIGHWAY ENGINEERING
9102	CV3103	DESIGN OF REINFORCED CONCRETE STRUCTURES
9102	CV3104	WASTE WATER MANAGEMENT
9102	CV3130	GEOTECHNICAL ENGINEERING LAB
9102	CV3131	ENVIRONMENTAL ENGINEERING LAB
9102	CV3201	APPLIED GEOTECHNICAL ENGINEERING
9102	CV3202	DESIGN OF STEEL STRUCTURES
9102	CV3204	WATER RESOURCES ENGINEERING
9102	CV3230	COMPUTER AIDED DESIGN LAB
9102	CV3231	HIGHWAY ENGINEERING LAB
9102	CV3233	ESTIMATION AND COSTING PRACTICE
9102	CV3270	PROJECT BASED LEARNING
9102	CV3241	ADVANCED DESIGN OF REINFORCED CONCRETE STRUCTURES
9102	CV3249	CONCRETE TECHNOLOGY
9102	CV3248	RAILWAYS AND AIRPORT ENGINEERING
9102	CV4170	MINOR PROJECT
9102	CV4171	INDUSTRIAL TRAINING
9102	CV4172	SURVEY CAMP
9102	CV4140	EARTHQUAKE RESISTANT DESIGN OF STRUCTURES
9102	CV4141	DESIGN OF PRE-STRESSED CONCRETE STRUCTURES
9102	CV4144	REPAIR AND REHABILITATION OF STRUCTURES
9102	CV4145	ADVANCED CONCRETE TECHNOLOGY
9102	CV4148	CONSTRUCTION PROJECT MANAGEMENT
9102	CV4149	GROUND IMPROVEMENT TECHNIQUES
9102	CV4150	ROCK MECHANICS AND UNDERGROUND EXCAVATION
9102	CV4152	TRAFFIC SYSTEMS AND ENGINEERING
9102	CV4270	MAJOR PROJECT
1014	BT6101	CELL & MOLECULAR BIOLOGY
1014	BT6102	FUNDAMENTAL & APPLIED MICROBIOLOGY
1014	BT6103	BIO-ANALYTICAL TECHNIQUES
1014	BT6130	BIOTECHNOLOGY LAB. I
1014	BT6131	BIOTECHNOLOGY LAB. II
1014	BT6170	SEMINAR
1014	BT6202	PLANT BIOTECHNOLOGY
1014	BT6203	GENETIC ENGINEERING
1014	BT6230	BIOTECHNOLOGY LAB. III
1014	BT6231	BIOTECHNOLOGY LAB. IV
1014	BT7101	ADVANCED GENETICS
1014	BT7102	BIOPROCESS ENGINEERING
1014	MA7117	STATISTICS FOR BIOLOGISTS

1014	BT7130	BIOTECHNOLOGY LAB. V
1014	BT7131	BIOTECHNOLOGY LAB. VI
1014	BT7140	ANIMAL BIOTECHNOLOGY
1014	BT7145	ENVIRONMENTAL BIOTECHNOLOGY AND APPLICATIONS
1014	BT7270	PROJECT DISSERTATION
1019	PY6101	ATOMIC, MOLECULAR & LASER PHYSICS
1019	PY6102	MATHEMATICAL PHYSICS
1019	PY6103	QUANTUM MECHANICS
1019	PY6104	ELECTRONICS
1019	PY6105	CLASSICAL MECHANICS
1019	PY6130	ELECTRONICS LAB
1019	PY6201	SOLID STATE PHYSICS
1019	PY6202	NUCLEAR AND PARTICLE PHYSICS
1019	PY6203	ELECTRODYNAMICS
1019	PY6230	SOLID STATE PHYSICS LAB
1019	PY6231	NUCLEAR PHYSICS LAB
1019	PY6232	SPECTROSCOPY LAB
1019	PY7101	STATISTICAL MECHANICS
1019	PY7102	ADVANCED QUANTUM MECHANICS
1019	PY7103	NUMERICAL METHODS AND PROGRAMMING
1019	PY7170	SEMINAR
1019	PY7130	COMPUTER LAB
1019	PY7270	MAJOR PROJECT

EVENTS

MUJ/DSW/Student Clubs/2023/Biotech Club MUJ/28th February

DIRECTORATE OF STUDENTS' WELFARE

Nukkad Natak

ON

Solid Waste Management

Department of Biosciences & Biotech Club, Manipal University Jaipur

Date of Event (28th February, 2023)

(Venue: TMA Pai Auditorium)

Index

S.No.	Activity Heads	Page no.
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2.	Objective of the Event	3
3.	Beneficiaries of the Event	3
4.	Brief Description of the event	3
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6.	Brochure or creative of the event	6
7.	Schedule of the Event	7
8.	Attendance of the Event	7

Introduction of the Event ,

The Department of Biosciences & Biotech Club, Manipal University Jaipur organized a 'Nukkad Natak' on 'Solid Waste Management' on 28th Feb, 23. It was directed by 2nd year students of Department of Biosciences, Divya and Samrat and it was awe-inspiringly performed by the students. This Nukkad Natak was under the guidance of the convenor – Dr. Mousumi Debnath, Faculty Coordinator, Biotech Club.

The performers interacted with the audience and presented an informatic skit on solid waste management and the do's and don'ts of waste disposal.

This skit was a call to action, urging the audience to take responsibility for their waste and make conscious choices in their daily lives. It was an effective way to educate and engage the public on a crucial environmental issue.

Objectives of the Event

- To increase awareness about solid waste management.
- To bring public awareness about the fatality caused by wastes.
- To educate about the waste disposal methods and its do's and don'ts.

Beneficiaries of the Event

- MUJ Students
- Faculty

Brief Description of the event

Conducted under the guidance of the Founder Faculty Coordinator, Biotech Club, Dr. Mousumi Debnath, Faculty of Biosciences, this Nukkad Natak solely aimed in bringing public awareness on solid waste management. It was well directed by students of Department of Biosciences, Divya and Samrat, who commenced from writing the scripts to directing the performers and eventually operated a successful and inspiring Nukkad Natak.

A group of brilliant and motivated performers presented the Nukkad Natak, bringing attention to the problem of solid waste management through a stirring and thought-provoking performance. The show highlighted the negative consequences of littering and the necessity of effective waste management.

The actors portrayed different characters like a litterbug, a garbage collector, and a responsible citizen who showed how the problem of solid waste management can be tackled. The audience was made conscious of the risks that incorrect garbage disposal poses to both the public's health and the environment.

The play also highlighted the role of the government and the civic bodies in managing solid waste.

In conclusion, the Nukkad Natak on Solid Waste Management held on 28th February on the occasion of National Science Day was a highly successful event that effectively highlighted the issue of solid waste management. The play succeeded in spreading awareness about the importance of proper waste management practices and the role of individuals and the government in tackling this issue.

Photographs

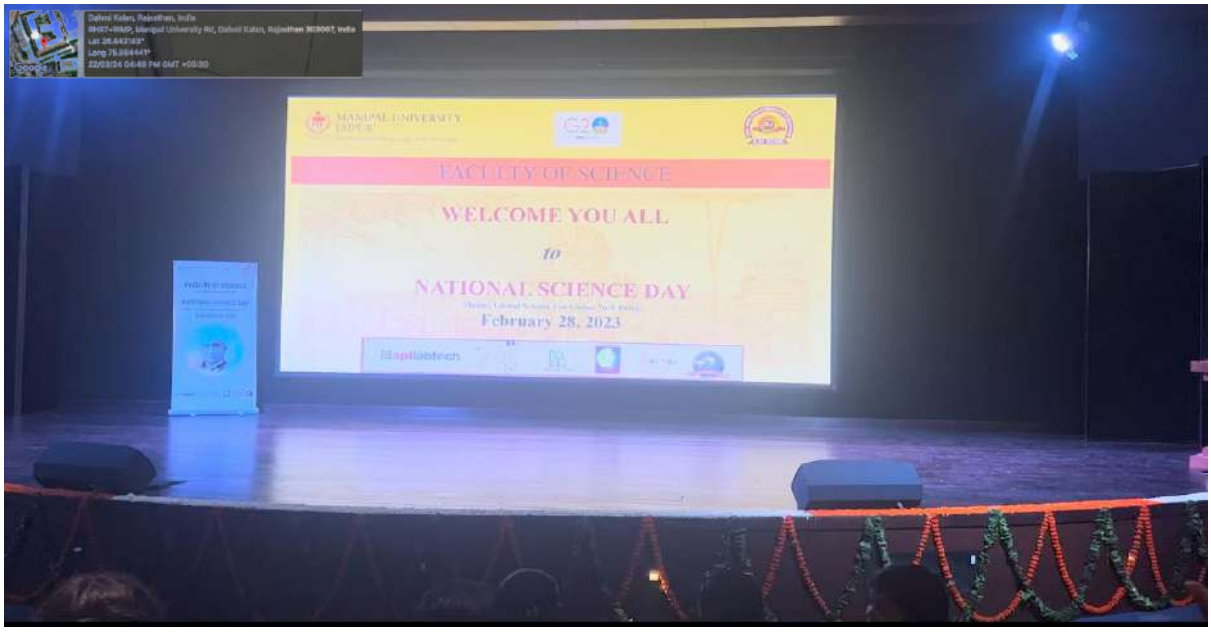

Figure 1 National Science Day; Coordinates: 26.843429; 75.566529; N26°50'36.34" E75°33'59.50"(Manipal University Jaipur)

Figure 2 Nukkad Natak performed by students.; Coordinates: 26.843429; 75.566529; N26°50'36.34" E75°33'59.50"(Manipal University Jaipur)

Figure 3 Nukkad Natak performed by students. Coordinates: 26.843429; 75.566529; N26°50'36.34" E75°33'59.50"(Manipal University Jaipur)

Figure 4 Nukkad Natak performed by students. Coordinates: 26.843429; 75.566529; N26°50'36.34" E75°33'59.50"(Manipal University Jaipur)

Figure 5 Nukkad Natak team and Dr. Mousumi Debnath, Faculty Coordinator, Biotech Club; Coordinates: 26.843429; 75.566529; N26°50'36.34" E75°33'59.50"(Manipal University Jaipur)

Brochure or Creative of the Event

MANIPAL UNIVERSITY
JAIPUR
(University under Section 2(f) of the UGC Act)
3.28 SCORE
Biotech Club
BIOTECH CLUB OF MUJ
Presents
NUKKAD NATAK
on
SOLID WASTE MANAGEMENT
DATE AND TIME
28th February, 2PM onwards
VENUE
TMA PAI auditorium, MUJ

Schedule of the event

The event was on the 28th February 2023 from 2:00 PM- 3:00 PM in TMA Pai Auditorium, Academic Block 2.

Attendance of the event: 38

S.No.	Name	Registration No.
1.	Ananya Singh	201002002
2.	Harsh Saxena	201003004
3.	Anvarshu Gopal	211002011
4.	Anshullika Saxena	211002053
5.	Ayushi Gupta	201002029
6.	Divya	211002056
7.	Sylvia Parveen	211003009
8.	Anushka Singh	211002003
9.	Shivani Tiwari	211002002
10.	Aryan Singh	211002038
11.	Muskan Yadav	211002040
12.	Sakshi Nirmal	211002060
13.	Priyasha Paul	211002035
14.	Akash Chandra	211002036
15.	Shashank Goyal	21102043
16.	Nandini	211003001
17.	Mrunal Mangaje	211003007
18.	Sowvhik Parvej	211002007
19.	Aayushi Thakkar	211002061
20.	Manisha Verma	211002009
21.	Rahul Shrivastava	211002050
22.	Debarghya Sarkar	211002015

23.	Samrat Banerjee	211003008
24.	Sneha Srivastava	211002042
25.	Sonali Lalwani	211002041
26.	Suhani Pareek	211002062
27.	Vishnu Priya	211002028
28.	Tarushi Jain	201003001
29.	Dr. Abhijeet Singh	
30.	Dr. Mousumi Debnath	
31.	Dr. Madan Mohan Sharma	
32.	Dr. Rakesh Sharma	
33.	Dr. Nitesh Poddar	
34.	Dr. Monika Sangani	

Ananya Singh

President, Biotech Cub MUJ

Signature of the Student Coordinator

Dr. Mousmai Debnath

School of Basic Science

Signature of the Faculty Coordinator

DIRECTOR STUDENT WELFARE & PROCTOR MANIPAL UNIVERSITY, JAIPUR	**Dr. Arun Kumar Poonia** Asst. Director, DSW Clubs

Name of Partnering Organizations:
Department of Electrical Engineering, Malaviya National Institute of Technology, Jaipur, India

Name of Participants:
P. Agrawal, N. Gupta, K. R. Niazi, A. Swarnkar

Name of the Activity:

Research Work on 'Distribution System Operation with Minimum Topological Variations'
(Book Chapter)

Distribution System Operation with Minimum Topological Variations

Praveen Agrawal, Neeraj Kanwar, Nikhil Gupta, K. R. Niazi, and Anil Swarnkar

Abstract Distribution network reconfiguration (DNR) is a well-established operational strategy for distribution systems to improve its performance. Also, several social and techno-economic objectives can also be effectively achieved in contemporary distribution systems by optimally placing distributed resources (DRs). However, with integration of DR, distribution system becomes active distribution systems and it has dynamically changing nature of load and generation. Therefore, it is important to reinvestigate the effectiveness of existing NR strategy. In this paper, a new NR strategy is suggested for power loss minimization where the network topology varied only once during a day. An investigation is carried about existing and proposed reconfiguration strategies while considering some realistic scenarios pertaining to contemporary distribution systems. The application results are shown on 33-bus test distribution system.

Keywords Distributed resources · Network reconfiguration · Smart grid

1 Introduction

In the present scenario, the distribution systems are taking new shapes by utilization of diverse distributed resources (DRs), automation in switching and other related control schemes, etc. On the other hand, the system performance is the biggest challenge in present competitive and deregulated environment. However, topological structure regulation of distribution networks can provide better electric power and more benefit to electric power companies [1]. This process is known as network reconfiguration (NR). However, the benefits of NR may be substantially reduced in the presence of optimally placed DRs as they can also effectively manage power

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S. K. Goyal et al. (eds.), *Flexible Electronics for Electric Vehicles*, Lecture Notes in Electrical Engineering 1065, https://doi.org/10.1007/978-981-99-4795-9_16

#UKLO Annual International Scientific Conference 2023

horizons International Scientific Journal University St. Kliment Ohridski in Bitola

SUSTAINABLE DEVELOPMENT GOALS

UKLO Annual International Scientific Conference 2023

On the occasion of the *World Science Day for Peace and Development*, the University "St. Kliment Ohridski" - Bitola is announcing a Call for Papers for its *Annual International Scientific Conference 2023* on the following topic:

"MULTIDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT GOALS"

Bitola, Republic of North Macedonia 17 - 18 November 2023

Mode: Hybrid

World Science Day for Peace and Development emphasizes the importance of science in society and the necessity to involve the broader public in discussions about emerging scientific topics. It highlights the value and applicability of science to our everyday lives.

The 2023 Conference topic is: "Multidisciplinary Approach to Sustainable Development Goals". Authors are invited to submit papers on any subject related to and within the scope of the Conference topic. Submissions from academics, researchers, and practitioners at any stage of their career, including PhD students, will be accepted.

Short overview:

World Science Day for Peace and Development, celebrated annually on 10 November, emphasizes the importance of science in society and the necessity to involve the broader public in discussions about emerging scientific topics. It highlights the value and applicability of science to our everyday lives. This international scientific conference offers the chance to mobilize the academy and experts from home and abroad around the issue of science for peace and development with a single purpose - *changing the world for the better!* The Conference will open for discussion on the most pressing issues of the UN Agenda 2030: 1. Eliminate Poverty; 2. Erase Hunger; 3. Establish Good Health and Well-Being; 4. Provide Quality Education; 5. Enforce Gender Equality; 6. Improve Clean Water and Sanitation; 7. Grow Affordable and Clean Energy; 8. Create Decent Work and Economic Growth; 9. Increase Industry, Innovation, and Infrastructure; 10. Reduce Inequality; 11. Mobilize Sustainable Cities and Communities; 12. Influence Responsible Consumption and Production; 13. Organize Climate Action; 14. Develop Life Below Water; 15. Life on Land; 16. Guarantee Peace, Justice, and Strong Institutions; 17. Build Partnerships for the Goals.

Important Dates:

- **20 September 2023:** Abstracts submission (up to 300 words in length)
- **17 and 18 November 2023:** Conference dates
- **05 December 2023:** Submission of final papers. Earlier submission of the papers helps us to manage the review process on time. Prepare your final paper following our Guidelines. Papers should be sent as .doc or .docx attachments via the e-mail address: conference@uklo.edu.mk

Submission details:
Interested authors are invited to submit an abstract (up to 300 words in length) and a brief academic CV written narratively by 20 September 2023 via the following link:
https://docs.google.com/forms/d/e/1FAIpQLSfxjz1J0DRQy7GYTCm11mdUffQWeDM_dn2gBh9SowUEKu3cSQ/viewform?vc=0&c=0&w=1&flr=0

Publication:
Submitted articles are subject to initial editorial screening and anonymous peer review by at least two reviewers. Selected papers will be published in a special issue of the *Horizons – International Scientific Journal* (https://uklo.edu.mk/ojs/index.php/horizons/index) as a peer-reviewed, interdisciplinary, and international journal published by the University St. Kliment Ohridski in Bitola, indexed in EBSCO, CrossRef, Google Scholar, etc.

Certification:
The papers accepted and presented during the Conference will receive a certification of participation.

Organizing Committee:

Prof. Dr. Sc Igor Nedelkovski, Rector, University "St. Kliment Ohridski" – Bitola
Prof. Dr. Sc Jasmina Bunevska-Talevska, Vice-Rector for Student Affairs, University "St. Kliment Ohridski" - Bitola
Prof. Dr. Sc Jove D. Talevski, Vice-Rector for Finance and Development, University "St. Kliment Ohridski" – Bitola
Prof. Dr. Sc Dragica Odžaklieska, Dean, Faculty of Economics-Prilep, University "St. Kliment Ohridski" – Bitola
Prof. Dr. Sc Mitko Kostov, Dean, Faculty of Technical Sciences-Bitola, University "St. Kliment Ohridski" - Bitola
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Prof. Dr. Sc Tanja Jovanovska, Director, Higher Medical School-Bitola, University "St. Kliment Ohridski" - Bitola
Prof. Dr. Sc Valentina Pelivanoska, Director, Tobacco Institute-Prilep, University "St. Kliment Ohridski" - Bitola

Conference Secretary:
Elena Kitanovska-Ristoska, PhD, University "St. Kliment Ohridski" - Bitola, North Macedonia

IT Consultant:
Assist. Prof. Dr. Blagoj Nenovski, University "St. Kliment Ohridski" - Bitola, North Macedonia

Short Article Guidelines

Article title: Times New Roman; 14 pt; bold; alignment centered; single-line spacing; All Caps (max. 100 characters with spaces).

Author details: Times New Roman; 12 pt; single-line spacing; alignment centered. Please write the author details in the following order:

John Galt
University "St. Kliment Ohridski" - Bitola, North Macedonia
ORCID iD: https://orcid.org/0000
E-mail: galt@uklo.edu.mk

Abstract and keywords: Between 150 and 200 words (5-7 keywords); Times New Roman; 12 pt; single-line spacing; justify. Write your abstract using concise, but complete, sentences. Get to the point quickly and always use the past tense because you are reporting on a study that has been completed. There are four things you need to include: 1) your research problem and objectives, 2) your methods, 3) your key results or arguments, and 4) your conclusion.

Article text: Times New Roman; 12 pt; justify; 1.0 line spacing; margins: Top: 2,5 cm; Bottom: 2,5 cm; Left: 3 cm; Right: 3 cm. The scope of submitted text should not exceed more than 30.000 characters (with spaces) including references. The text should be written in the neuter gender, concisely with correct orthography. Latin phrases should be set in *italics*.

Quotations: If they are brief (3 lines or fewer), quotations should be run on with the text. Longer quotations should be indented, without quotation marks. All indented quotations should be typed single-spaced.

Citation style: The author should follow Chicago Style (author-date system) for referencing, for example: (Dahl 1989, 45); (Geddes 1999, 134-43); (Linz 1975). All references should be given in full at first mention. Subsequent citations can be abbreviated. Footnotes should be kept to a minimum.

Headings and subheadings: Times New Roman; 12 pt; bold.

Tables: Times New Roman; bold; size 10; align heading left; single line spacing. Tables must be created in Word, not Excel. The table heading is situated above the table.

Figures: Times New Roman; bold; size 10; alignment centered; single line spacing. The authors must submit original electronic copies of the figures applied in the article in TIFF, JPG, or PNG format. Figure heading is situated under the figure. Consider aligning tables and figures at the center.

Dates: Dates should be given in the form: 26 December 1981.

Conclusion: The conclusion is intended to help the reader understand why your research should matter to them after they have finished reading the article. A conclusion is where you summarize the article's findings and generalize their importance, discuss ambiguous data, and recommend further research.

These include:

- Presenting the last word on the issues you raised in your article.
- Summarizing your thoughts and conveying the larger implications of your study.
- Demonstrating the importance of your ideas.
- Introducing possible new or expanded ways of thinking about the research problem.

References: The reference list appears at the end of your article, and provides more detailed information about the sources you cited. Each entry in the reference list also begins with the author's last name and the publication date, so that your reader can easily find any source they encounter in the text. For four or more authors, list all of the authors in the reference list; in the text, list only the first author, followed by *et al*. It is alphabetized by the author's last name.

References Examples:

Articles:
Author's surname, Name. year of publication. "Article Title". *Horizons* 8 (1):229-4, DOI: XXX-XXX
Books:
Author's surname, Name. year of publication. *Book Title*. place of publication: publisher.
Contributions in compilations and edited volumes:
Author's surname, Name. year of publication. "Title", In: editor's surname, forename initials (ed./eds.) Compilation (place of publication: publisher), pages interval, DOI: XXX-XXX
Internet (URL):
When articles, books, or official documents are accessed via the internet, the reference should be formatted as described above; Full URL. where the document is posted should be listed as well as the date when it was accessed.
Author's surname, Name. year of publication. *Book Title*. place of publication: publisher, available at: http://xxxxxxxxxxxxxxxx (26 December, 2021).
Legislation: Acts and Regulations
The titles of pieces of legislation (Acts, Regulations, rules, and by-laws) should be cited exactly - do not alter spelling or capitalization.
In-Text Citation:
Title of the Act Year
Title of the Act Year (abbreviation of the jurisdiction)
References:
Title of the Act and Date of publication (abbreviation of the jurisdiction)

Note: Legislation is fully included in a list of references, in alphabetical order among other references.

***We suggest utilizing reference management software like Zotero, Mendeley, and similar tools.**

Organizer:
University "St. Kliment Ohridski" - Bitola, Republic of North Macedonia

For more information about the Conference, please contact us:
Contact phone: +389 47 223 788
E-mail: conference@uklo.edu.mk
Web page: www.uklo.edu.mk

We appreciate your interest in our Conference and looking forward to your submission soon. Please forward this information to your colleagues and students.

Kind Regards,
Conference Organizing Team

Fw: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>

Thu 13/07/2023 17:04

To:goran.ilik@uklo.edu.mk <Goran.ilik@uklo.edu.mk>;nurten.sulejmani@uklo.edu.mk <nurten.sulejmani@uklo.edu.mk>
Cc:Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>;Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>

2 attachments (425 KB)

AISC 2023_Call for Papers.pdf; Manipal Logo.jpeg;

Respected Sir

Manipal University Jaipur logo is attached in the mail. We are thankful for the collaboration.

https://jaipur.manipal.edu/

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From: Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>
Sent: 13 July 2023 17:00
To: Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>
Cc: Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>
Subject: FW: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Dear Prabhpreet,

Please share the University Logo and Link with the University St. Kliment Ohridski, Bitola for the International Conference.

Regards

From: Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>
Sent: Wednesday, July 12, 2023 7:32 PM

To: Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>
Cc: Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>; Dr. Santosh Patil [MU - Jaipur] <santosh.patil@jaipur.manipal.edu>; goran.ilik@uklo.edu.mk
Subject: Fwd: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Respected Madam
St. Kliment Ohridski Bitola are organising International conference. It is hereby requested for logo and link. Trail mail for kind consideration.

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From: Nurten Sulejmani <nurten.sulejmani@uklo.edu.mk>
Sent: Wednesday, July 12, 2023 5:49 PM
To: Goran Ilik <goran.ilik@uklo.edu.mk>; REKTOR Korunovski <rector@uklo.edu.mk>
Subject: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Respected colleagues,

As partner universities with established relations of bilateral cooperation, it is our distinct pleasure to inform you about a major scientific event *Annual International Scientific Conference 2023*, organized by the University "St Kliment Ohridski" – Bitola, Republic of North Macedonia to be held on 17-18 November 2023, on the occasion of celebrating the World Science Day for Peace and Development.

The Conference topic is "Multidisciplinary Approaches to Sustainable Development Goals". Authors are invited to submit papers on any subject related to and within the scope of the Conference topic. Submissions from academics, researchers, and practitioners at any stage of their career, including PhD students, will be accepted. Selected papers will be published in a special issue of the *Horizons - International Scientific Journal* as a peer reviewed, interdisciplinary, and international journal published by the University "St. Kliment Ohridski" - Bitola, indexed in EBSCO, CrossRef, Google Scholar etc. The language of the Conference is English.

We now invite abstract submissions for the Conference (by 20 September 2023) at the following link:
https://docs.google.com/forms/d/e/1FAIpQLSfxjz1J0DRQy7GYTCm11mdUffQWeDM_dn2gBh9SowUEKu3cSQ/viewform?vc=0&c=0&w=1&flr=0

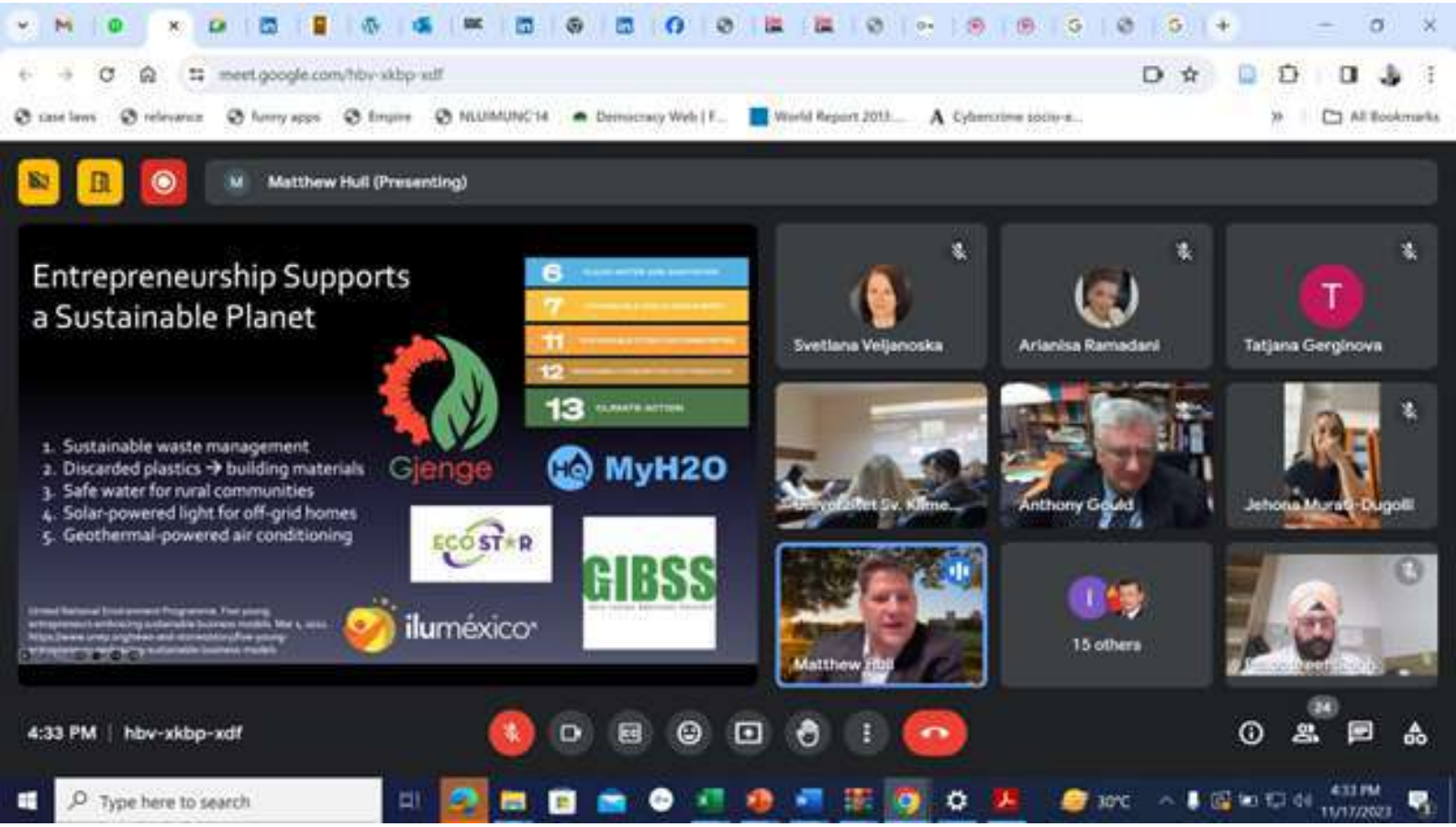
To that end, we would be very glad to share it with our friends and invite our partner universities to be presented with the institutional logo and link to their institutional web to act as Conference partners and friends. The main benefit for the Conference partners would be the free publication of accepted papers. So, before we share the detailed information about the Conference – time, venue, and program – we would very much appreciate having your consent accompanied by your institutional logo and a link no later than 31 July 2023 submitted via emails: goran.ilik@uklo.edu.mk and nurten.sulejmani@uklo.edu.mk

After that, we will get back to you with further steps as soon as possible.

Looking forward to hearing from you,

Organizing Team
Ms Nurten Sulejmani
IR Officer

University "St. Kliment Ohridski" - Bitola
Bulevar 1 Maj bb
7000 Bitola
Republic of N. Macedonia
+ 389 71 217 422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Matthew Hull (Presenting)
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2. Discarded plastics → building materials
3. Safe water for rural communities
4. Solar-powered light for off-grid homes
5. Geothermal-powered air conditioning
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MyH2O
ECOSTAR
GIBSS
iluméxico
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Arianisa Ramadani
Tatjana Gerginova
Anthony Gould
Jehona Murati-Dugolli
Matthew Hull
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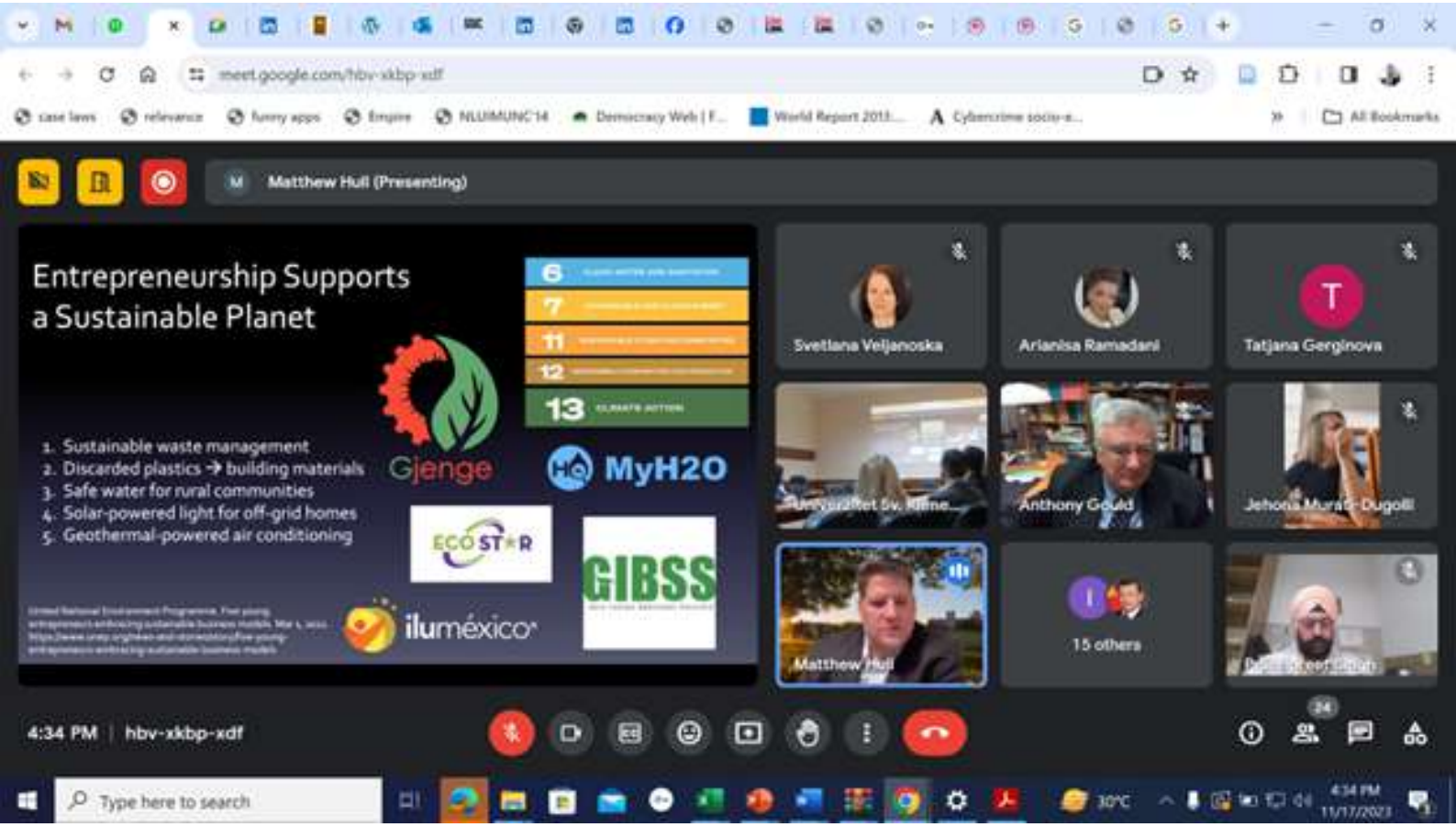
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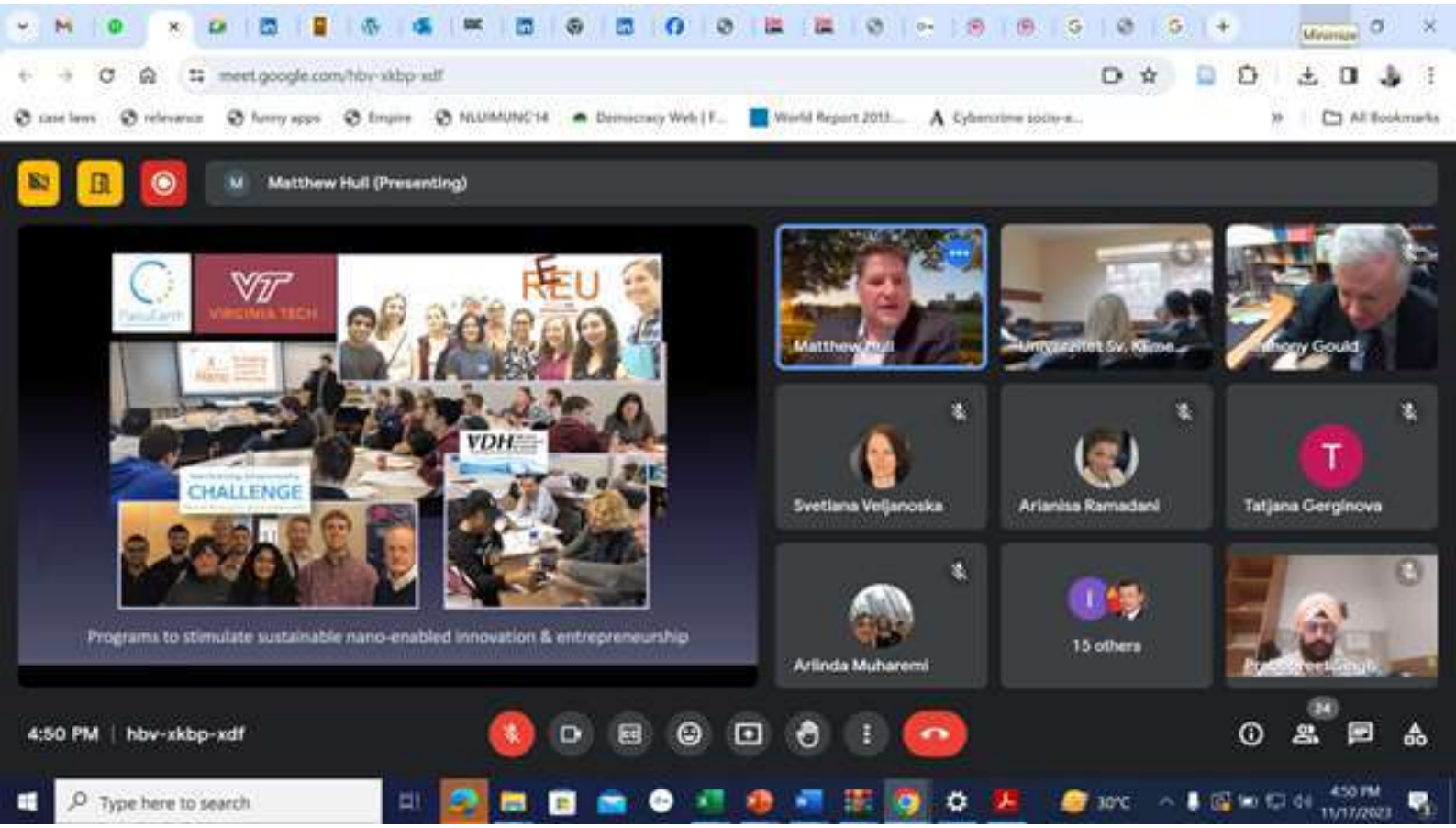
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Matthew Hull (Presenting)
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Matthew Hull (Presenting)
NanoTechnology Entrepreneurship Challenge (NTEC)
Promote student-led entrepreneurship across NNCI
Flexible support to maximize site engagement
Opportunity to:
NTEC Showcase
Matthew Hull
Anthony Gould
Svetlana Veljanoska
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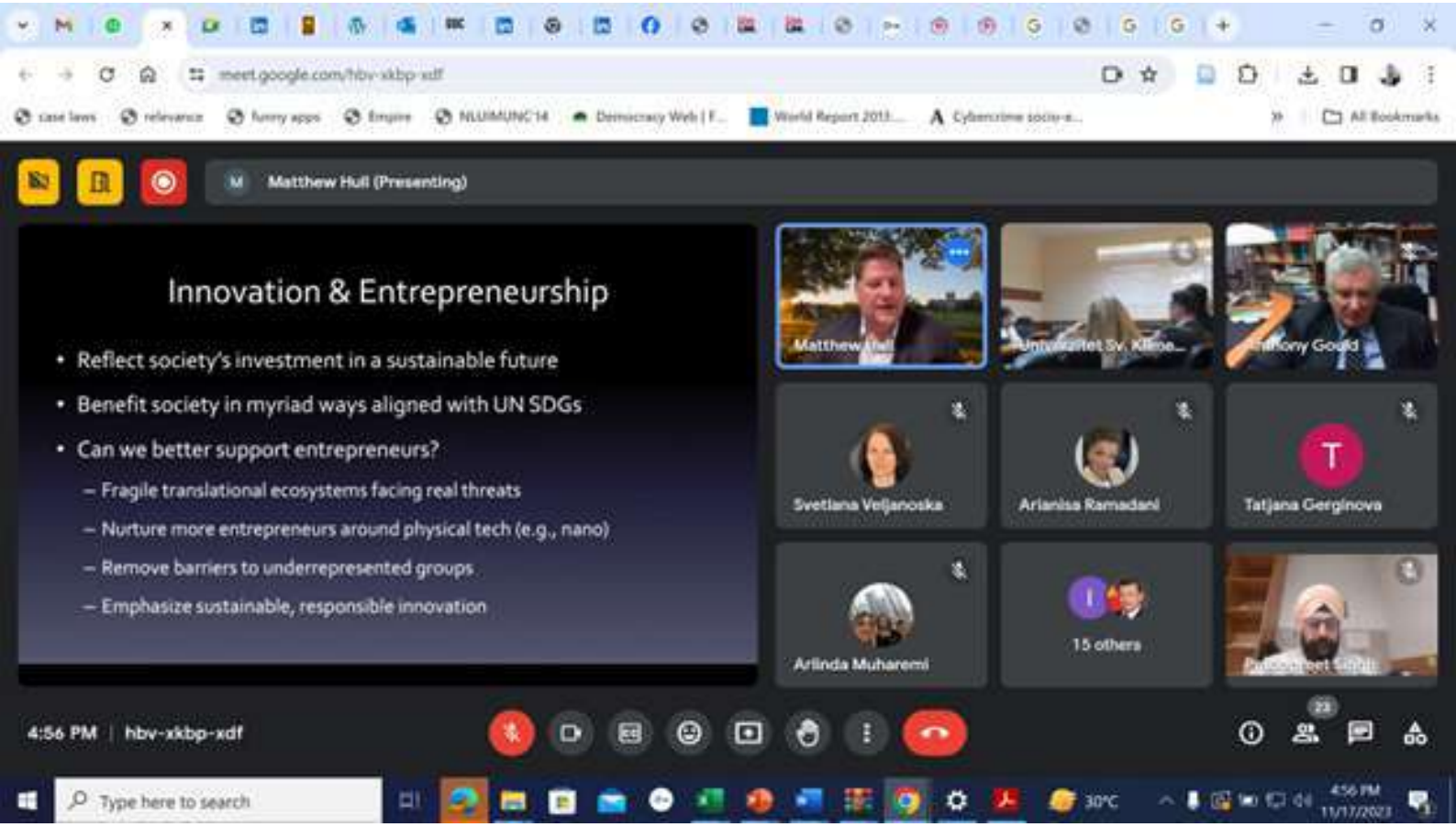
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Innovation & Entrepreneurship
• Reflect society's investment in a sustainable future
• Benefit society in myriad ways aligned with UN SDGs
• Can we better support entrepreneurs?
– Fragile translational ecosystems facing real threats
– Nurture more entrepreneurs around physical tech (e.g., nano)
– Remove barriers to underrepresented groups
– Emphasize sustainable, responsible innovation
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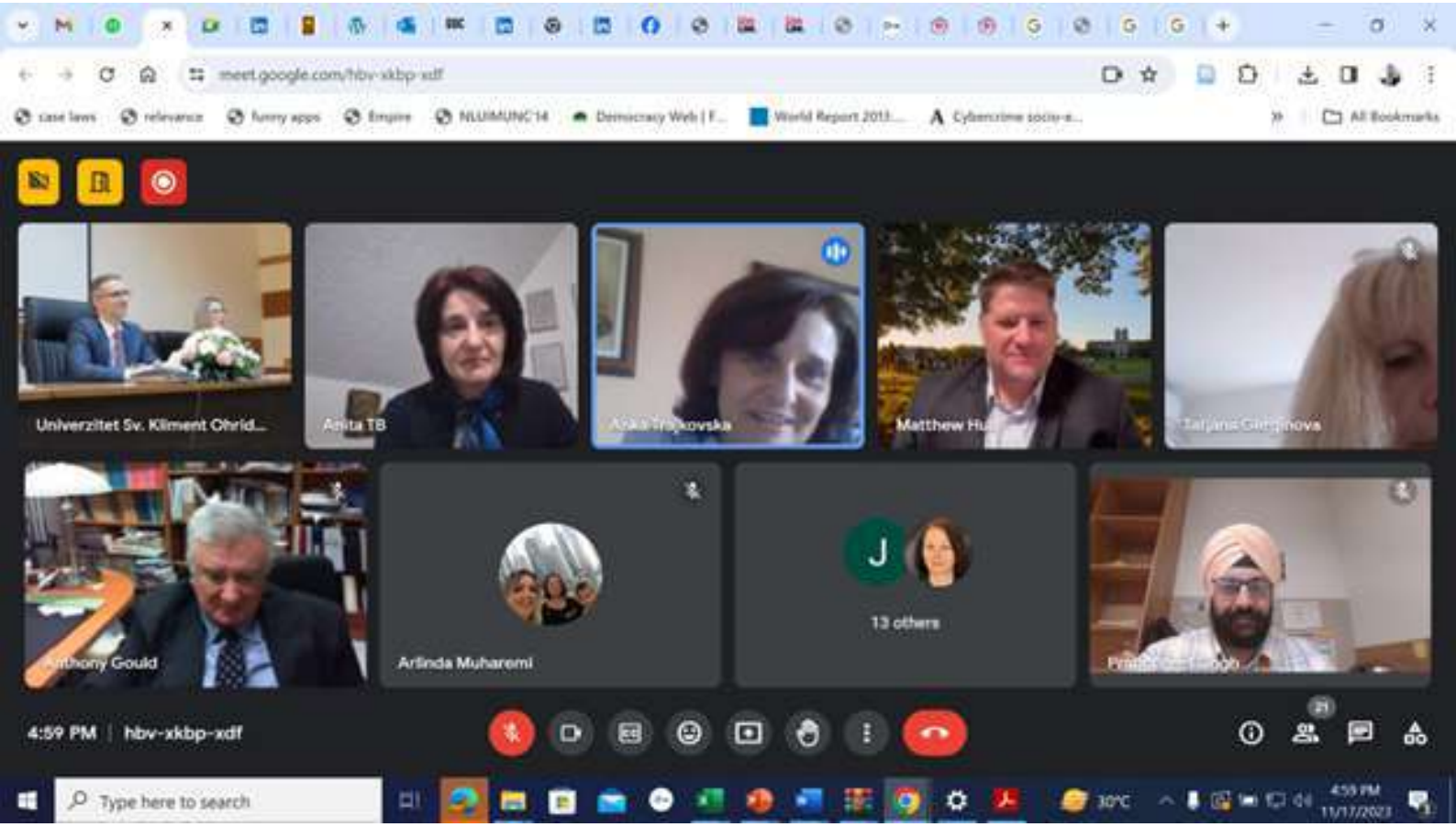
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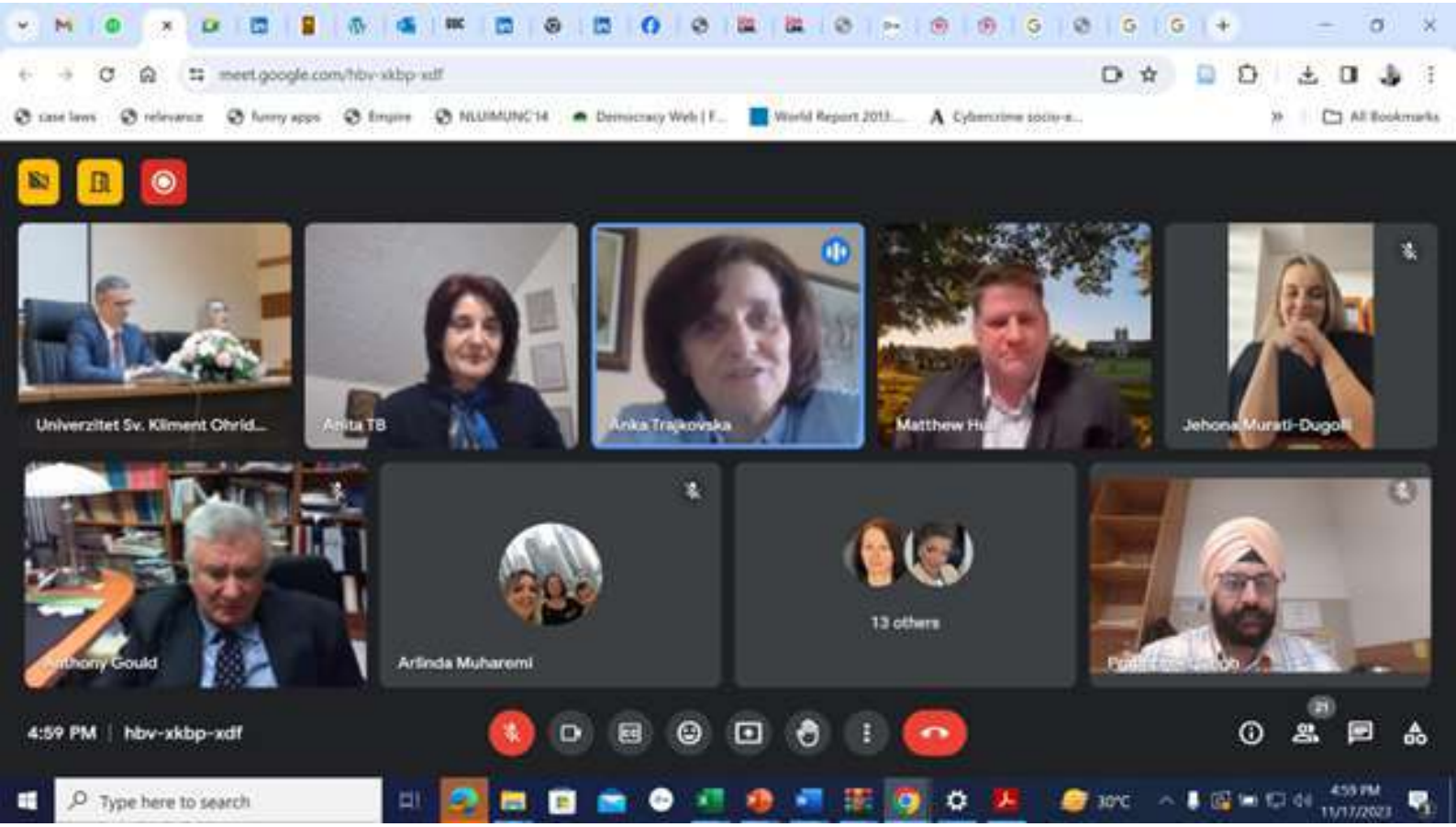
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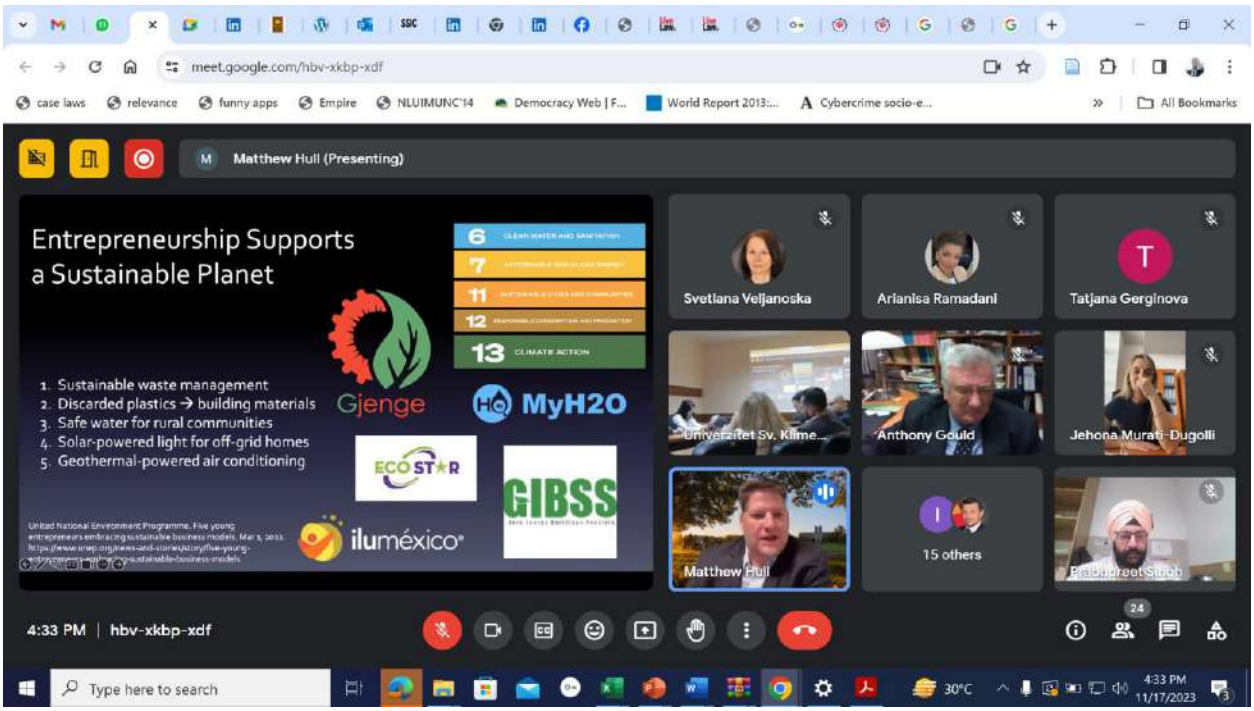
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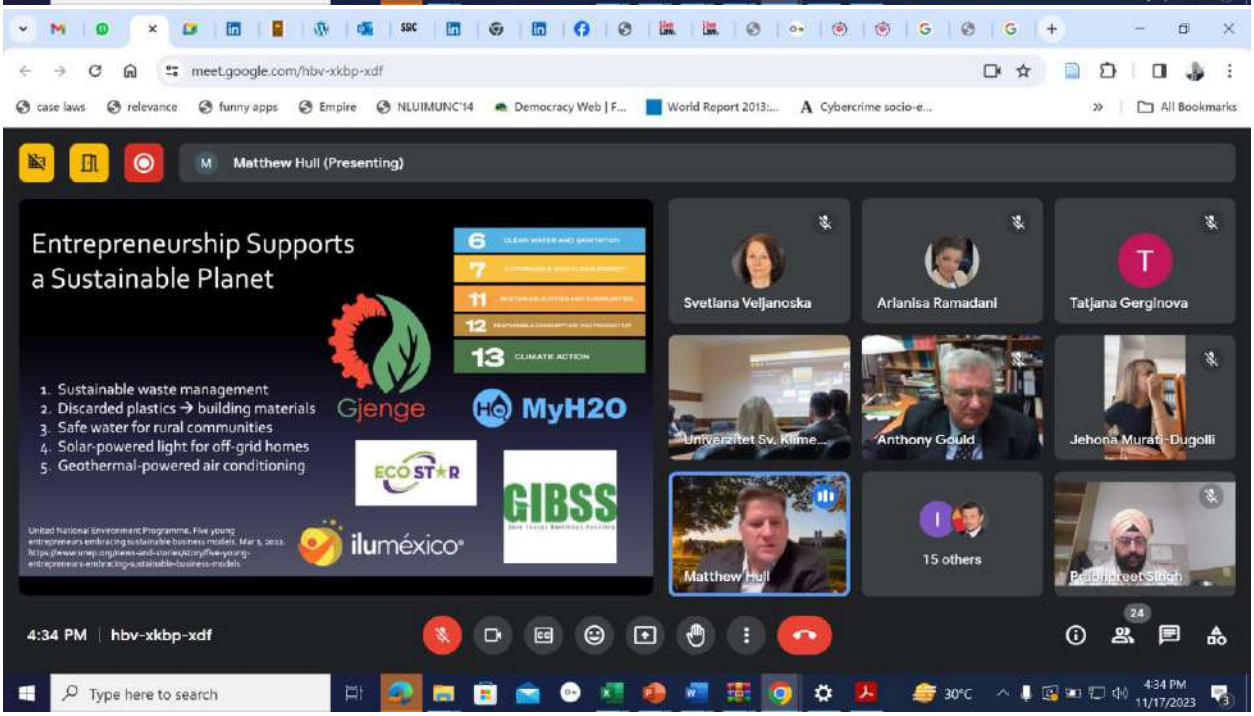
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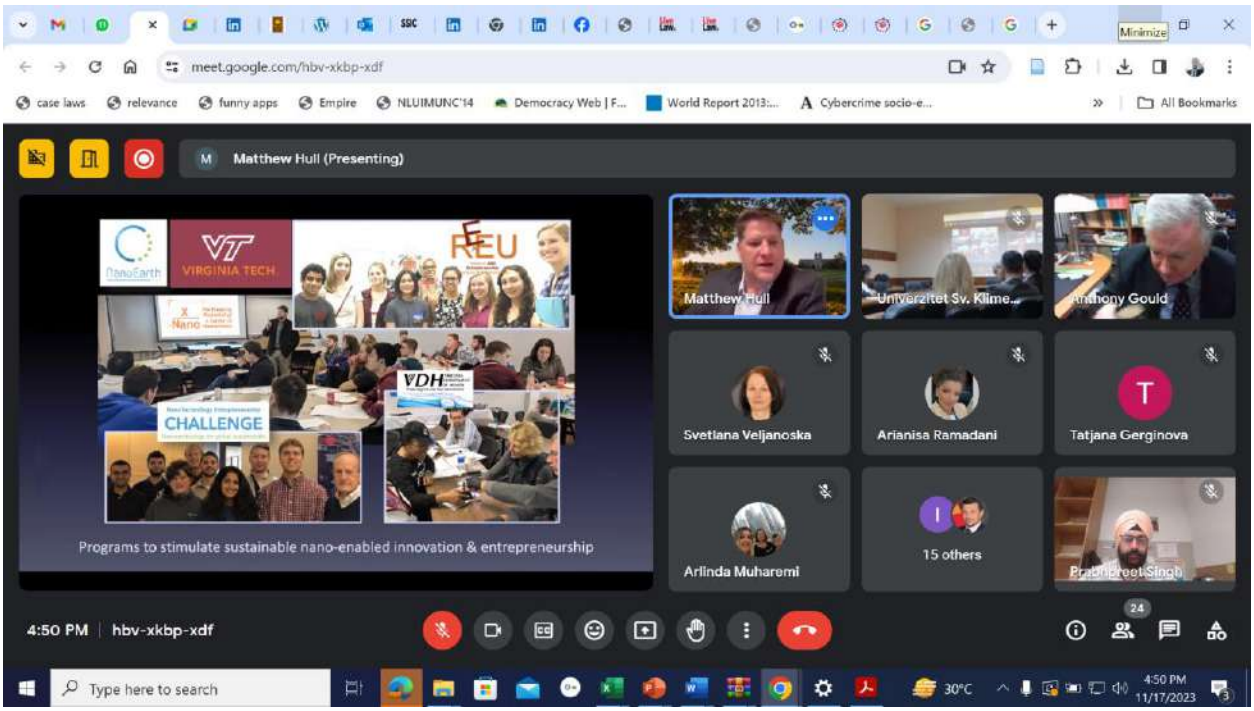
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NanoTechnology Entrepreneurship Challenge (NTEC)
Promote student-led entrepreneurship across NNCI
Flexible support to maximize site engagement
In-kind instrument time
Direct funding ($500/team for instrument time, materials)
Diversity Award (support for underrepresented groups)
Voluntary participation in 7-week NTEC Accelerator
Opportunity to:
Explore nano for sustainable solutions
Learn, "practice" entrepreneurship
Transition ideas beyond the lab
Fail safely, learn from mistakes
Connect NNCI sites
NTEC Showcase
Matthew Hull
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Anthony Gould
Svetlana Veljanoska
Arianisa Ramadani
Tatjana Gerginova
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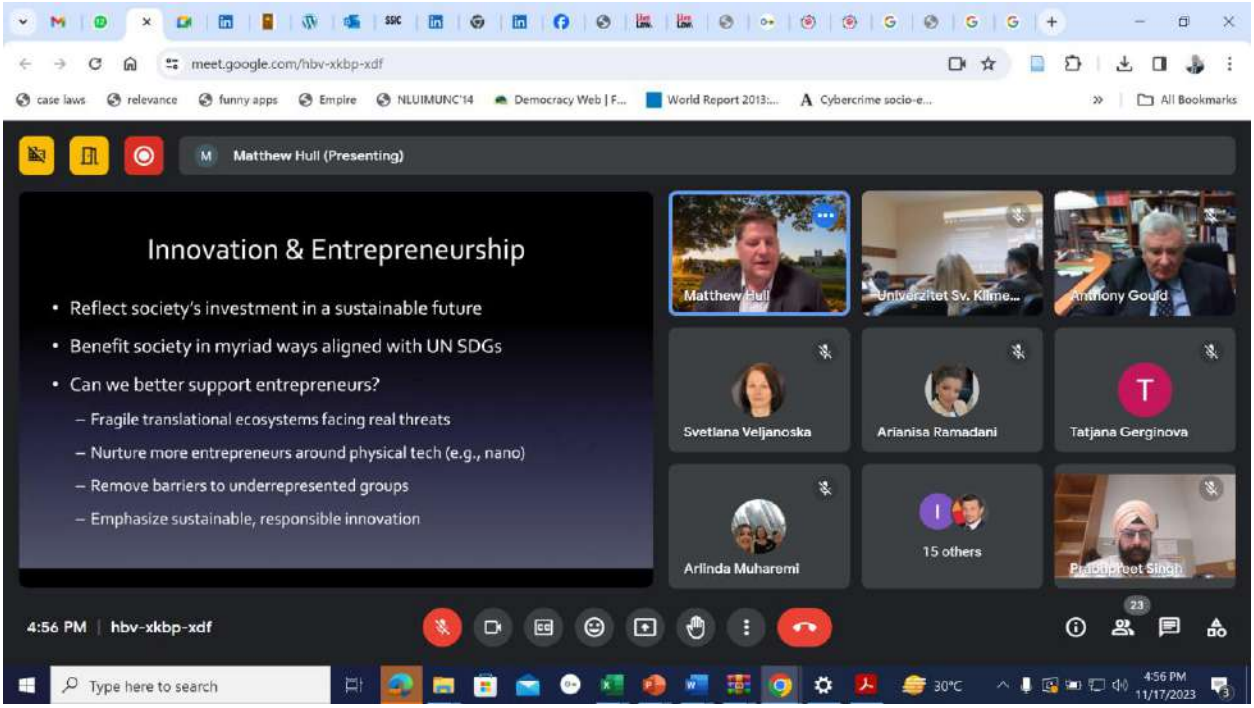
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Innovation & Entrepreneurship
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Prabupreet Singh
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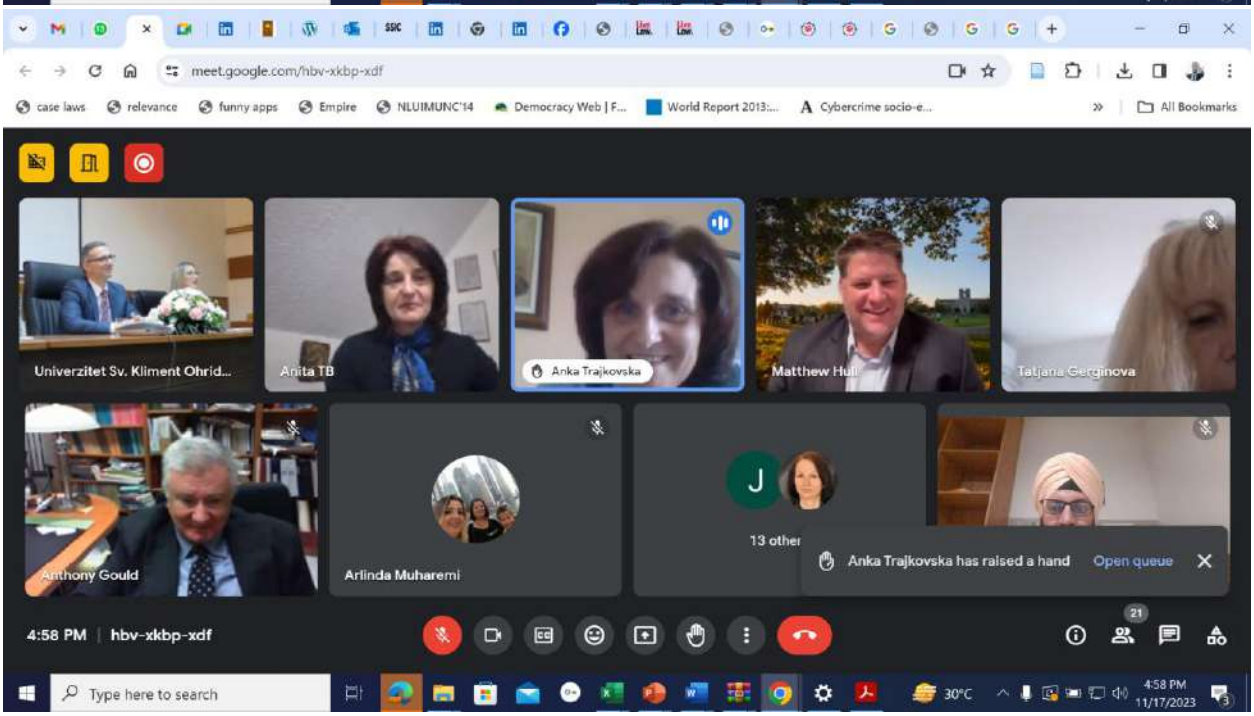
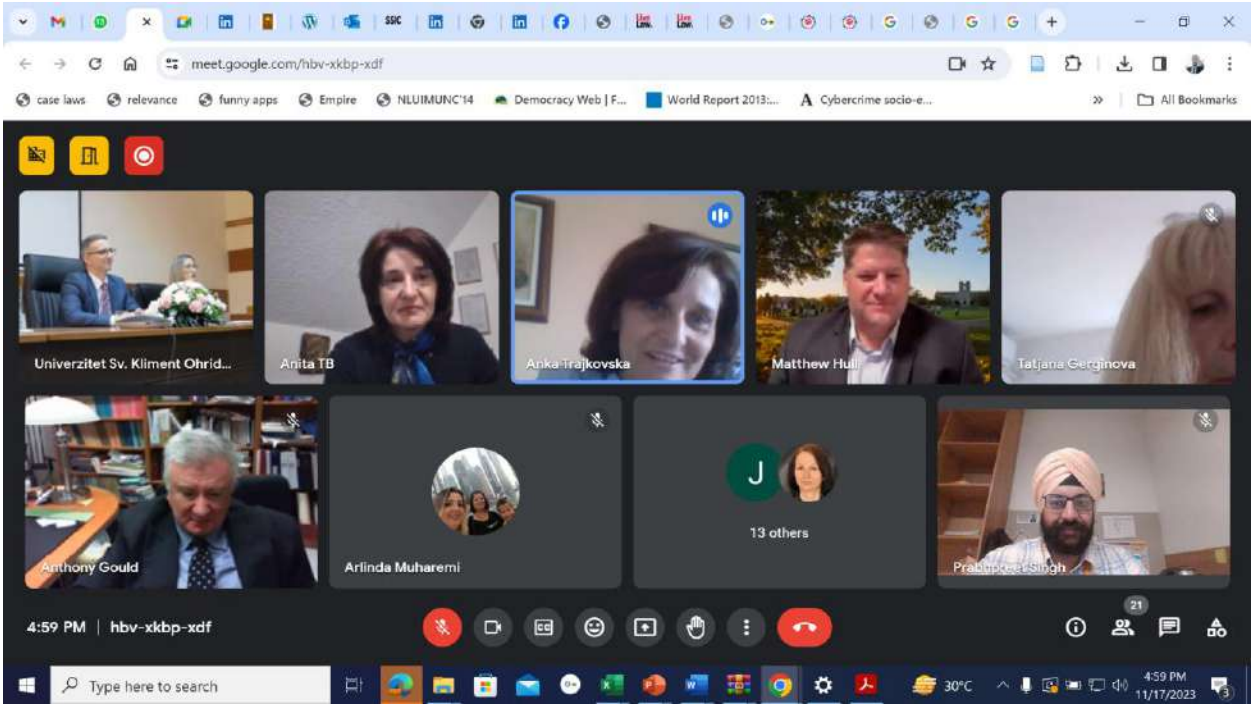
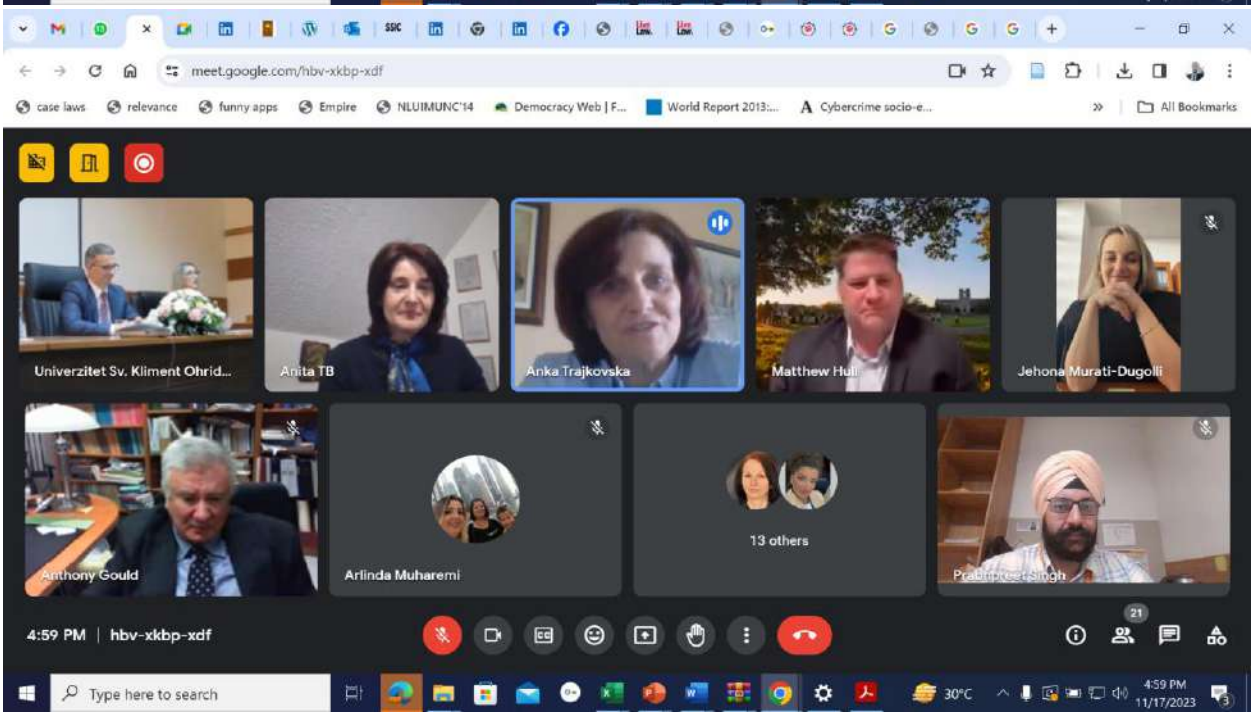

meet.google.com/hbv-xkbp-xdf
Univerzitet Sv. Kliment Ohrid...
Anita TB
Anka Trajkovska
Matthew Hull
Tatjana Gerginova
Anthony Gould
Arlinda Muharemi
13 other
Anka Trajkovska has raised a hand
Open queue
4:58 PM | hbv-xkbp-xdf





Manipal University Jaipur is a partner university in a major scientific event Annual International Scientific Conference 2023, organized by the University “St Kliment Ohridski” – Bitola, Republic of North Macedonia to be held on 17-18 November 2023, on the occasion of celebrating the World Science Day for Peace and Development. The Conference topic is “Multidisciplinary Approaches to Sustainable Development Goals”. I want to thank Professor Goran Ilik for the kind opportunity and Collaboration.

Also, this is the Second International Conference in which both the Universities are Collaborating. University “St Kliment Ohridski” – Bitola, Republic of North Macedonia was a partner university in 4th International Conference on Smart Systems: Innovations in Computing organized by School of Information Technology, Manipal University Jaipur.

https://lnkd.in/du_vb_mT

UKLO Annual International Scientific Conference 2023 (AISC)

World Science Day for Peace and Development, celebrated annually on November 10th, highlights the significance of science in society and the imperative to engage the wider public in discussions regarding emerging scientific subjects. On this occasion, the University "St. Kliment Ohridski" - Bitola is hosting the *Annual International Scientific Conference 2023* on the following topic:

"MULTIDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT GOALS"

Bitola, Republic of North Macedonia, 17 November 2023
Starting Time: 11:00 CET
Language: English & Macedonian
Place: UKLO Conference Hall (Onsite) & Online
Mode: Hybrid

This AISC offers the chance to mobilize the academy and experts from home and abroad around the issue of science for peace and development with a single purpose - ***changing the world for the better!***

The AISC will focus on discussing the key issues outlined in the UN Agenda 2030. These include eliminating poverty, eradicating hunger, improving health and well-being, ensuring quality education, promoting gender equality, enhancing access to clean water and sanitation, advancing affordable and clean energy, fostering decent work and economic growth, encouraging industry, innovation, and infrastructure development, reducing inequality, building sustainable cities and communities, advocating for responsible consumption and production, addressing climate action, protecting life below water and on land, ensuring peace, justice, and strong institutions, and fostering partnerships to achieve these goals.

AISC Partners:

"Sustainable development requires human ingenuity. People are the most important resource".

- **Dr. Dan Shechtman***

** Dr. Shechtman was awarded with a Nobel Prize in Chemistry in 2011. In 2023, Professor Honoris Causa title was given to Dr. Shechtman at the University "St. Kliment Ohridski" – Bitola.*

Place: UKLO Conference Hall (Onsite)

10:30 – 11:00 Registration of participants

11:00 – 11:30 Opening ceremony (Onsite & Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

Prof. Dr. sc Igor Nedelkovski, Rector of the University "St. Kliment Ohirdski" - Bitola

Prof. Dr. sc Goran Ilik, Vice-Rector for Science at the University "St. Kliment Ohirdski" - Bitola

Dr. Toni Konjanovski, Mayor of Bitola

Dr. Bisera Kostadinovska – Stojchevska, Minister of Culture of the Republic of North Macedonia

Plenary speakers:

11:35 – 12:00

Anthony M. Gould, PhD, Laval University, Canada

Speech: *"Zero-Sum versus Positive Sum: Sustainable Growth through a Change in Mindset"*

(Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

12:05 – 12:30

Matthew S. Hull, PhD Research Professor/Director, NCFL | Virginia Tech ICTAS, USA

Speech: *"Sustainable Entrepreneurship: A Catalyst for the UN Agenda 2030"*

(Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

12:30 – 12:45 Discussion

12:45-13:00 Coffee break

Moderator: Prof. Dr. Ivona Shushak - Lozanovska

AISC Partners:

#UKLO Annual International Scientific Conference 2023

horizons International Scientific Journal University St. Kliment Ohridski in Bitola

PRESENTATION SCHEDULE

17 November 2023

PANEL I

13:00 – 15:15 UKLO Conference Hall (Onsite)

Chair: Prof. dr. sc Ice Ilijevski	
1. Svetlana Nikolovska – EFFICIENCY AND EFFICIENCY OF THE STATE AUTHORITIES AND INSTITUTIONS IN THE SUPPRESSION OF CORRUPTION IN THE REPUBLIC OF NORTH MACEDONIA	13:00-13:15 Onsite
2. Katerina Krstevska - Savovska– PROHIBITION OF TORTURE – MACEDONIAN CRIMINAL LEGISLATION AND COMPARATIVE OVREVIEW	13:15-13:30 Onsite
3. Marina Malish Sazdovska – SUSTAINABLE DEVELOPMENT AS A GLOBAL PHENOMENON	13:30-13:45 Onsite
4. Tatjana Gerginova – GLOBAL SUSTAINABLE DEVELOPMENT	13:45-14:00 Onsite
5. Ice Ilijevski, Ivona Shushak – Lozanovska, Angelina Stanojoska–PROVIDING A "LEGAL IDENTITY" FOR ALL – THE CASE OF THE REPUBLIC OF NORTH MACEDONIA	14:00-14.15 Onsite
6. Gordana Gjorgievska – Nedelkovski, Fatma Bajram, Azemovska – OUR LIBRARY AND SUSTAINABLE DEVELOPMENT GOALS	14:30-14:45 Onsite
7. Liljana Jonoski – A LEVEL OF CONTRIBUTION TO THE AGENDA 2030 THROUGH THE ENFORCEMENT OF GENDER EQUALITY IN NORTH MACEDONIA	14:45-15:00 Onsite
8. Laze Jakimoski – FREEDOM OF AGREEMENT AS A GENERAL PRINCIPLE OF LAW AND ITS LIMITS	14:15-14:30 Onsite
Discussion (Onsite)	15:00-15:15

AISC Partners:

WOXSEN UNIVERSITY

MANIPAL UNIVERSITY JAIPUR (University under Section 2(f) of the UGC Act)

PANEL II

13:00 – 15:15 Online: Google Meet Link: https://meet.google.com/hbv-xkbp-xdf

Chair: Prof. dr. sc Aleksandar Ivanov (aleksandar.ivanov@uklo.edu.mk)	
1. Svetlana Veljanovska – ACCESS TO PUBLIC INFORMATION AS A FUNDAMENTAL DEMOCRATIC RIGHT OF CITIZENS	13:00-13:15 Online
2. Agustina Noeli Vasquez – THE DEVELOPMENTAL ETHOS OF PRESIDENTIAL CANDIDATES IN ARGENTINA: A QUALITATIVE ANALYSIS OF THE 2023 ELECTION DEBATE	13:15-13:30 Online
3. Milan Masat- THE SIGNIFICANCE OF THE EVENTS OF THE SHOAH FOR CONTEMPORARY SOCIETY	13:30-13:45 Online
4. Marina Kalashlinska – THE GOVERNMENT PREPAREDNESS TO RESTRICT THE CIVIL LIBERTIES OF MEDIA AS A CRITERION FOR THE PROLIFERATION OF ANTI-DEMOCRATIC TENDENCIES IN UKRAINE	13:45-14:00 Online
5. Branko Leštanin, Željko Nikač – LEGAL AND ORGANIZATIONAL ASPECTS OF FIGHT AGAINST NARCO-CRIMES IN SERBIA:STATE AND DEVELOPMENT	14:00-14.15 Online
6. Marina Kuzmanovska- THE FAMILY AS A FACTOR IN ENCORAGING OF THE GIFTEDNESS	14:15-14:30 Online
7. Avkash Jadhav – EXAMINING RIGHT TO LIFE AS THE CORE VALUE OF SUSTAINABLE DEVELOPMENT GOALS	14:30-14:45 Online
8. Panche Dameski – CLINICAL EVALUATION OF SURGICAL TREATMENT OF CHERRY EYE WITH MODIFIED MORGAN POCKET TECHNIQUE	14:45-15:00 Online
Discussion (Online)	15:00-15:15

15:15-15:30 CLOSING REMARKS (Onsite and Online: Google Meet Link)

Note: Selected papers presented at the AISC will be published in a special issue of "Horizons - International Scientific Journal", an interdisciplinary, peer-reviewed, and internationally recognized journal published by the University "St. Kliment Ohridski" - Bitola. The journal is indexed in databases such as EBSCO, CrossRef, Google Scholar and more.

Organizer: University "St. Kliment Ohridski" – Bitola, Republic of North Macedonia
Contact phone: +389 47 223 788
E-mail: conference@uklo.edu.mk
Web page: www.uklo.edu.mk

Place: Partizanska 32, Bitola 7000

AISC Partners:

"Sustainable development is the pathway to the future we want for all. It offers a framework to generate economic growth, achieve social justice, exercise environmental stewardship and strengthen governance."

- **Ban Ki-moon**

Conference Partners:

WOXSEN UNIVERSITY

MANIPAL UNIVERSITY JAIPUR
(University under Section 2(f) of the UGC Act)

MEDITERRANEA INTERNATIONAL CENTRE FOR HUMAN RIGHTS RESEARCH

AISC Partners:

WOXSEN UNIVERSITY

MANIPAL UNIVERSITY JAIPUR
(University under Section 2(f) of the UGC Act)

MANIPAL UNIVERSITY
JAIPUR

Post Event Report

FACULTY OF DESIGN

5days Executive Development Program on

‘Bamboo Renaissance: Modern Design Meets Sustainability’

Venue: Online platform

Time: 9:30 AM-12.00 PM (First day)

2:30 PM-4.00 PM (2nd to 5th day)

18th September- 22nd September 2023

Index

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2. Objectives of the Executive development Program 3

3. Beneficiaries of the Event: 3

4. Details of the Guests 3

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6. Images 5

7. Brochure of the event 6

8. Schedule of the event 7

9. Attendance of the Event 7

10. Weblink 7

11. Event Coordinators: 7

1. Introduction of the Executive development Program:

On World Bamboo Day, the Faculty of Design at Manipal University Jaipur organized a 5-day Executive Development Program titled "Bamboo Renaissance: Modern Design Meets Sustainability" in collaboration with their industrial partner, KONBAC, and the Indian Bamboo Forum, in association with the IGBC Student Chapter, MUJ, and MUJ-TEC. The program was conducted in virtual mode from September 18th to September 22nd, 2023.

2. Objectives of the Seminar:

- Understanding the various application of Bamboo in Exterior and interior spaces.
- To create awareness about bamboo in different regions.
- To understand its production and preservation technique techniques.

3. Beneficiaries of the Event:

- UG Students (Architecture, Design and Construction related Fields)
- PG Students (Architecture, Design and Construction related Fields)
- Research Scholars
- Academicians, Practitioners, and Industry Professionals in the fields of Architecture, Design, Civil, and Structural Engineering.

4. Details of the Speakers:

a) Dr. Jagdish Vengala, Head of EDC & Associate Professor at PVPSIT Vijayawada. Dr. Jagdish Vengala presented various components of bamboo and explained its diverse strength and elastic properties. He also discussed the various IS codes applicable in India for bamboo construction.

b) Prof. Sankalp, an associate professor from CEPT UNIVERSITY. Prof. Sankalp presented various construction techniques related to Bamboo construction, demonstrating proposals from different parts of the world. He elucidated innovative joinery details pertinent to bamboo construction.

c) Prof. Charruchandra K. faculty member at CTARA, IIT Mumbai,discussed various species of bamboo and highlighted their unique thermal, bending, tensile, and compressive strength properties. He also showcased the application of innovative joinery details using Bomcrete (HIB) technology in arch construction. In addition, Prof. Charruchandra K. presented models of bamboo structures subjected to different loads, demonstrating their strength and durability.

d) **Mr. Sanjeev Shashikant Karpe** is a qualified Electrical Engineer has been associated with bamboo Industry for last eighteen years and has pioneered the work in setting up of self-sustainable bamboo-based enterprise in rural India. He is a Founder and Director with Konkan Bamboo & Cane Development Centre (KONBAC), an organization working for sustainable development through use of bamboo as a resource & implementing various bamboo projects successfully for last 17 years. Mr. Sanjeev Karpe explained bamboo construction in India and worldwide.

He stated that bamboo has strong potential to grow in degraded land, requires less water compared to sugarcane, and consumes less embodied energy compared to conventional materials. In the global context, countries such as Colombia and Vietnam have embarked on large-scale bamboo projects, whereas in India, despite being the world's second-largest bamboo producer, its full potential remains largely untapped. In addition, Ar. Sanjeev Karpe presented models of bamboo structures subjected to different loads, demonstrating their strength and durability. Various experiments related to straightening of bamboo and bending it to achieve the required form were also demonstrated.

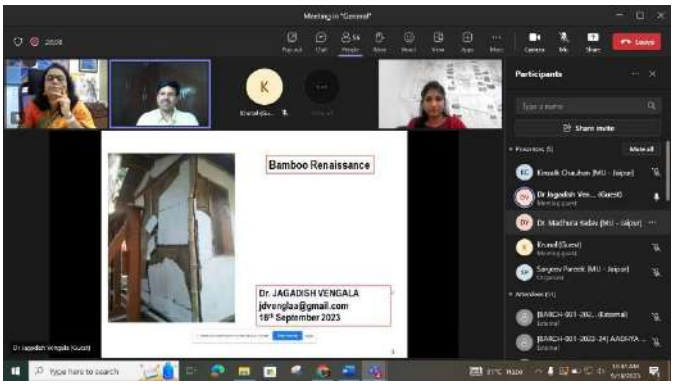
e) Mr. Amitava Sil, a Scientist at IWST (Indian Wood Science and Technology), Kolkata, renowned for his extensive knowledge and experience in the preservation treatment of bamboo species. Mr. Amitava Sil provided insights into preservative treatments and fire retardancy in structural bamboo. He elucidated various treatment methods and processes, highlighting their associated benefits. Furthermore, he offered a demonstration of bamboo's structural frame by showcasing its inherent structural properties.

5. Brief Description of the event:

In the context of a Global Environmental crisis, coupled with economic and health challenges, the time has come for radical cultural awareness, politicians. architects, engineers, developers, and construction companies have an enormous responsibility as the construction industry and processes have an enormous negative impact on the environment. Bamboo is a key natural resource and, together with conscious design, draws a new direction for Contemporary Architecture. The Executive Development Program "Bamboo Renaissance: Modern Design Meets Sustainability is a comprehensive initiative designed to explore the dynamic intersection of modern design principles and sustainable practices within the realm of bamboo. This program is carefully curated to provide Industry Professionals, Academicians, and Researchers with the knowledge and tools needed to harness bamboo's immense potential as an eco-friendly resource in contemporary design and construction. The EDP 2023 will be a great opportunity to facilitate networking with industry experts and peers, enabling participants to exchange ideas, collaborate on projects, and stay updated on emerging trends and innovations in sustainable design.

6. Images

1.Inaugural Address by Prof. (Dr.) Madhura Yadav, Dean, FoD



2. . First day expert lecture by Prof. (Dr.) Jagdish Vegala

3. . Second day expert lecture by Prof. (Dr.) Sankalp

4. . Third day expert lecture by Prof. (Dr.) Charuchandra

5. . Fourth day expert lecture by Mr. Sanjeev Karpe

6. . Fifth day expert lecture by Mr. Amitava Sil

7. . Valedictory session by Mr. Anand Mishra and Mr. Dhirendra Madan

7.Brochure of the event:

MANIPAL UNIVERSITY JAIPUR
(University under Section 2(f) of the UGC Act)

FACULTY OF DESIGN
in association with
IGBC Student Chapter, MUJ & MUJ TEC
in collaboration with
KONBAC Community, First
IBF India Bamboo Forum

EXECUTIVE DEVELOPMENT PROGRAM -2023 (Virtual Mode)
September 18th: 9:30am to 11 am & September 19th to 22nd, 2023 ; 2:30pm to 4:00 pm

BAMBOO RENAISSANCE:
Modern Design meets Sustainability

Scan here for Registration
Scan here for Payment

ABOUT MANIPAL UNIVERSITY JAIPUR
Manipal University Jaipur (MUJ) has redefined academic excellence in the region and inspires students of all disciplines to learn and innovate through hands-on practical experience. The multi-disciplinary university offers career-oriented courses at all levels, i.e., UG, PG, and doctoral across all the streams like Engineering, Architecture, Planning, Fashion Design, Interior Design, Fine Arts, Hospitality, Humanities, Journalism, Basic Sciences, Law, Commerce, Computer Applications, Management, etc. The university has been granted the ATAL Incubation Centre , funded by Niti Aayog, Government of India. Ost.

ABOUT FACULTY OF DESIGN
The Faculty of Design aims to nurture it as one of its core strengths, with the mission to become the most preferred global destination in design education and research for students, researchers, faculty, collaborators, promoters, investors, and developers. Over time, the Faculty has grown into two Schools: The School of Architecture and Design, & the School of Design & Art & and many departments. The Faculty of Design is backed by excellent infrastructure; and intellectual capital within the Faculty. At present Faculty of Design is offering UG, PG, and Doctoral programs in Architecture, Interior Design, Fine Art, Fashion Design and UXID.

IGBC STUDENT CHAPTER
IGBC Student Chapter Manipal University Jaipur was constituted by the Faculty of Design. IGBC student chapter aims to explore the role of the green building concept in the built and unbuilt environment. The chapter organized various interactive sessions and workshops by experts.

KONBAC BAMBOO PRODUCTS PRIVATE LIMITED
KONBAC BAMBOO PRODUCTS PRIVATE LIMITED is classified as a non-government company and it is registered and located in MUMBAI. KONBAC provides training, at a national and global level, in Bamboo cultivation, harvesting, and primary and secondary processing Manufacture of interior & and lifestyle accessories Manufacture of home and office furniture Construction of cottages, resorts, and buildings.

ABOUT EXECUTIVE DEVELOPMENT PROGRAMME
In the context of a Global Environmental crisis, coupled with economic and health challenges, the time has come for radical cultural awareness. politicians, architects, engineers, developers, and construction companies have an enormous responsibility as the construction industry and processes have an enormous negative impact on the environment. Bamboo is a key natural resource and, together with conscious design, draws a new direction for Contemporary Architecture.
The Executive Development Program 'Bamboo Renaissance: Modern Design Meets Sustainability' is a comprehensive initiative designed to explore the dynamic intersection of modern design principles and sustainable practices within the realm of bamboo. This program is carefully curated to provide Industry Professionals, Academicians, and Researchers with the knowledge and tools needed to harness bamboo's immense potential as an eco-friendly resource in contemporary design and construction.
The EDP 2023 will be a great opportunity to facilitate networking with industry experts and peers, enabling participants to exchange ideas, collaborate on projects, and stay updated on emerging trends and innovations in sustainable design.

CHIEF GUEST
Hon'ble Mr. SURESH PRABHU

GUEST OF HONOUR
DR PRABHAT KUMAR

RESOURCE PERSONS
Mr. SANJEEV KARPE, Founder Director, KONBAC
Prof. SANKALPA, Associate Prof., PA, CEPT University
Mr. AMITAVA SIL, Scientist, IWST Kolkata
Dr. JAGADISH VENGALA, Head, EDC & Associate Professor, PVPIET, Vijayawada
Prof. CHAREUCHANDRA K, Faculty, CTARA, IIT, Mumbai
SPECIAL GUEST
Mr ANAND MISHRA, Chairman, IGBC Jaipur & Managing Director, Trimurty Builders & Calculators Pvt. Ltd

OUR CHAIRS
CHIEF PATRON
MR. S. VAITHEESWARAN
Chairperson, Manipal University Jaipur

PATRON
Dr. G K PRABHU
President, Manipal University Jaipur

CO-PATRON
Dr. THAMMAIAH CS
Pro-President, Manipal University Jaipur

CO-PATRON
Dr. NITU BHATNAGAR
Registrar, Manipal University Jaipur

CONVENER
Dr. MADHURA YADAV
Dean FOD, Manipal University Jaipur

ORGANISING SECRETARIES
Ar. SANJEEV PAREEK
Asst. Prof. SAE-D
Ar. KINZALK CHAUHAN

WHO CAN PARTICIPATE
Students, Research Scholars, Academicians, and Practitioners in the field of Architecture, Design, Civil, and Structural Engineering.

REGISTRATION FEE
INR 500 - For External Participants
INR 200 - For Research Scholars & Internal Participants

NOTE
After the successful Completion of EDP, an E-Certificate will be given to all participants

MANIPAL UNIVERSITY JAIPUR
FACULTY OF DESIGN
Celebrating World Bamboo Day
By Organising
EXECUTIVE DEVELOPMENT PROGRAM -2023 (Virtual Mode)
BAMBOO RENAISSANCE:
Modern Design meets Sustainability
in association with MUJ TEC & IGBC STUDENT CHAPTER, MUJ
in collaboration with KONBAC IBF
DATE & TIME: (1 hour 30 minutes/Day)
September 18th: 9:30 am to 11 am
& September 19th to 22nd, 2023: 2:30 pm to 4:00 pm
INAUGURAL FUNCTION
CHIEF GUEST
GUEST OF HONOUR
RESOURCE PERSONS
VALEDICTORY FUNCTION
CHIEF GUEST
GUEST OF HONOUR
OUR CHAIRS
CHIEF PATRON
PATRON
CO PATRON
CO PATRON
CONVENER
ORGANISING SECRETARIES
REGISTRATION FEE
REGISTRATION LINK
PAYMENT LINK

8 .Schedule of the event

S.No.	Description	Time
1	Welcome Address by **Prof. (Dr.) Madhura Yadav, Director, SA&D, Manipal University Jaipur**	9.30 AM
2	Inaugural Address by **Hon'ble Mr. Suresh Prabhu, Member of Parliament, India's Sherpa to G7 & G20**	9.35 AM
3	Address by **Prof. (Dr.) Anuradha Chatterjee, Dean, FoD, Manipal University Jaipur**	9.45 AM
4	Address by **Mr. Sanjeev Karpe, Director, KONBAC Maharashtra**	9.55 AM
5	Presidential Address by **Prof. (Dr.) G. K. Prabhu, President, Manipal University Jaipur**	10.10 AM
6	Vote of Thanks by **Prof. Kinzalk chauhan, SA&D, Manipal University Jaipur**	10.20 AM
7.	Fist day Expert Lecture by Dr. Jagdish Vengela	10.30 AM

9. Attendance of the Event:

S.No	Full Name	Timestamp
1	Sanjeev Pareek [MU - Jaipur]	22/9/23, 5:55:52 pm
2	Guest	22/9/23, 3:54:07 pm
3	Guest	22/9/23, 5:54:52 pm
4	Archish Bahl	22/9/23, 6:00:51 pm
5	Archish Bahl	22/9/23, 4:04:18 pm
6	Archish Bahl	22/9/23, 4:11:51 pm
7	Archish Bahl	22/9/23, 5:55:55 pm
8	Nikhitha Naresh Moily [B.Des - ID - 2020]	22/9/23, 4:00:54 pm
9	Nikhitha Naresh Moily [B.Des - ID - 2020]	22/9/23, 4:01:23 pm
10	Nikhitha Naresh Moily [B.Des - ID - 2020]	22/9/23, 4:46:28 pm
11	Dr. Ashutosh Saini [MU - Jaipur]	22/9/23, 4:02:27 pm
12	Guest	22/9/23, 4:04:52 pm
13	Guest	22/9/23, 5:04:44 pm
14	Guest	22/9/23, 5:05:01 pm
15	Guest	22/9/23, 5:27:51 pm
16	Guest	22/9/23, 5:27:53 pm
17	Guest	22/9/23, 5:53:48 pm
18	Guest	22/9/23, 2:05:19 pm
19	Guest	22/9/23, 4:40:13 pm
20	Guest	22/9/23, 4:48:16 pm
21	Guest	22/9/23, 5:02:02 pm
22	Guest	22/9/23, 5:02:06 pm
23	Guest	22/9/23, 5:30:05 pm
24	Anjali Adhikari [B ARCH - 2021]	22/9/23, 2:08:17 pm
25	Anjali Adhikari [B ARCH - 2021]	22/9/23, 4:10:46 pm
26	Anjali Adhikari [B ARCH - 2021]	22/9/23, 4:50:36 pm
27	Anjali Adhikari [B ARCH - 2021]	22/9/23, 5:31:09 pm
28	Anjali Adhikari [B ARCH - 2021]	22/9/23, 5:41:07 pm
29	Anjali Adhikari [B ARCH - 2021]	22/9/23, 5:53:53 pm
30	Guest	22/9/23, 4:11:20 pm
31	Guest	22/9/23, 5:53:40 pm
32	Guest	22/9/23, 4:13:26 pm
33	Guest	22/9/23, 4:55:11 pm
34	Guest	22/9/23, 4:56:23 pm
35	Guest	22/9/23, 5:24:41 pm
36	Digvijay Singh Panwar [B.Arch - 2022]	22/9/23, 2:13:23 pm
37	Digvijay Singh Panwar [B.Arch - 2022]	22/9/23, 5:54:03 pm
38	Ananya Tandon [B.Arch - 2022]	22/9/23, 4:14:54 pm
39	Ananya Tandon [B.Arch - 2022]	22/9/23, 4:21:25 pm
40	Ananya Tandon [B.Arch - 2022]	22/9/23, 4:21:47 pm
41	Ananya Tandon [B.Arch - 2022]	22/9/23, 5:31:24 pm
42	Dr. Madhura Yadav [MU - Jaipur]	22/9/23, 4:15:23 pm
43	Dr. Madhura Yadav [MU - Jaipur]	22/9/23, 5:53:44 pm
44	Guest	22/9/23, 4:15:58 pm
45	Guest	22/9/23, 5:55:58 pm
46	Vanshika Sharma [B.Arch - 2022]	22/9/23, 4:17:00 pm
47	Vanshika Sharma [B.Arch - 2022]	22/9/23, 4:31:11 pm
48	Vanshika Sharma [B.Arch - 2022]	22/9/23, 2:52:54 pm
49	Vanshika Sharma [B.Arch - 2022]	22/9/23, 5:53:54 pm
50	Guest	22/9/23, 4:19:15 pm
51	Guest	22/9/23, 5:55:08 pm
52	Kinzalk Chauhan [MU - Jaipur]	22/9/23, 4:20:11 pm
53	Kinzalk Chauhan [MU - Jaipur]	22/9/23, 5:55:49 pm
54	Guest	22/9/23, 2:21:10 pm
55	Guest	22/9/23, 4:22:13 pm
56	Guest	22/9/23, 4:22:16 pm
57	Guest	22/9/23, 4:34:10 pm
58	Guest	22/9/23, 4:34:12 pm
59	Guest	22/9/23, 5:10:30 pm
60	Guest	22/9/23, 4:22:46 pm
61	Guest	22/9/23, 5:51:03 pm
62	Dr. Sunanda Kapoor [MU - Jaipur]	22/9/23, 4:24:48 pm
63	Dr. Sunanda Kapoor [MU - Jaipur]	22/9/23, 5:48:49 pm
64	Dr. Richa Jagatramka [MU - Jaipur]	22/9/23, 2:25:00 pm
65	Dr. Richa Jagatramka [MU - Jaipur]	22/9/23, 4:25:35 pm
66	Dr. Subhash Chandra Devrath [MU - Jaipur]	22/9/23, 4:25:15 pm
67	Dr. Subhash Chandra Devrath [MU - Jaipur]	22/9/23, 2:58:51 pm
68	Dr. Subhash Chandra Devrath [MU - Jaipur]	22/9/23, 4:56:45 pm
69	Dr. Subhash Chandra Devrath [MU - Jaipur]	22/9/23, 5:54:34 pm
70	Guest	22/9/23, 2:25:53 pm
71	Guest	22/9/23, 4:34:10 pm
72	Nehal Jain [B.Arch - 2022]	22/9/23, 4:26:08 pm
73	Nehal Jain [B.Arch - 2022]	22/9/23, 5:07:23 pm
74	Raunak Prasad [MU - Jaipur]	22/9/23, 4:26:49 pm
75	Raunak Prasad [MU - Jaipur]	22/9/23, 4:53:24 pm
76	Raunak Prasad [MU - Jaipur]	22/9/23, 5:19:20 pm
77	Raunak Prasad [MU - Jaipur]	22/9/23, 5:19:57 pm
78	Annie Iqbal [B.Arch - 2020]	22/9/23, 4:30:35 pm
79	Annie Iqbal [B.Arch - 2020]	22/9/23, 2:50:51 pm
80	Ritu Sharma [PHD - 2020]	22/9/23, 4:30:52 pm
81	Guest	22/9/23, 4:33:54 pm
82	Guest	22/9/23, 4:34:17 pm
83	Guest	22/9/23, 4:34:25 pm
84	Guest	22/9/23, 5:28:35 pm
85	Guest	22/9/23, 4:34:56 pm
86	Guest	22/9/23, 5:53:34 pm
87	Guest	22/9/23, 2:57:08 pm
88	Guest	22/9/23, 5:43:40 pm
89	Ishika Singhal [B-ARCH - 2019]	22/9/23, 4:38:08 pm
90	Ishika Singhal [B-ARCH - 2019]	22/9/23, 5:55:58 pm
91	Pavani Pandey [B-ARCH - 2019]	22/9/23, 4:38:12 pm
92	Pavani Pandey [B-ARCH - 2019]	22/9/23, 5:53:54 pm
93	Sneh Singh [MU - Jaipur]	22/9/23, 2:59:28 pm
94	Sneh Singh [MU - Jaipur]	22/9/23, 5:54:02 pm
95	Nandini Rawat [B-ARCH - 2019]	22/9/23, 4:40:02 pm
96	Nandini Rawat [B-ARCH - 2019]	22/9/23, 2:55:03 pm
97	Nandini Rawat [B-ARCH - 2019]	22/9/23, 4:56:05 pm
98	Nandini Rawat [B-ARCH - 2019]	22/9/23, 4:56:19 pm
99	Nandini Rawat [B-ARCH - 2019]	22/9/23, 2:58:07 pm
100	Nandini Rawat [B-ARCH - 2019]	22/9/23, 5:38:17 pm
101	HARSH VARDHAN PATHAK [B.Arch - 2019]	22/9/23, 4:41:49 pm
102	HARSH VARDHAN PATHAK [B.Arch - 2019]	22/9/23, 5:55:51 pm
103	[BARCH-001-2023-24] A ANANYA	22/9/23, 4:42:30 pm
104	[BARCH-001-2023-24] A ANANYA	22/9/23, 2:44:48 pm
105	[BARCH-001-2023-24] A ANANYA	22/9/23, 2:05:11 pm
106	[BARCH-001-2023-24] A ANANYA	22/9/23, 4:46:13 pm
107	[BARCH-001-2023-24] CHANDRIKA VERMA	22/9/23, 4:42:42 pm
108	[BARCH-001-2023-24] CHANDRIKA VERMA	22/9/23, 4:40:18 pm
109	Arunima Kiro [B-ARCH - 2019]	22/9/23, 4:42:42 pm
110	Arunima Kiro [B-ARCH - 2019]	22/9/23, 5:53:54 pm
111	[BARCH-001-2023-24] AANYA GUPTA	22/9/23, 4:42:45 pm
112	[BARCH-001-2023-24] AANYA GUPTA	22/9/23, 5:07:14 pm
113	Aamera Quazi [M. Des (Major Interior Design) - 2022]	22/9/23, 4:43:56 pm
114	Aamera Quazi [M. Des (Major Interior Design) - 2022]	22/9/23, 4:48:30 pm
115	Pushpak Bhagwati	22/9/23, 4:44:49 pm
116	Guest	22/9/23, 2:10:59 pm
117	Guest	22/9/23, 4:53:40 pm
118	Guest	22/9/23, 2:08:33 pm
119	Guest	22/9/23, 5:40:51 pm
120	Guest	22/9/23, 5:40:56 pm
121	Guest	22/9/23, 5:49:49 pm
122	Pooja (Guest)	22/9/23, 4:47:12 pm
123	Pooja (Guest)	22/9/23, 5:37:10 pm
124	Pooja (Guest)	22/9/23, 5:43:22 pm
125	Aashima Mathur [B-ARCH - 2019]	22/9/23, 4:47:19 pm
126	Aashima Mathur [B-ARCH - 2019]	22/9/23, 5:08:34 pm
127	Aashima Mathur [B-ARCH - 2019]	22/9/23, 5:08:52 pm
128	Maroi [B.Arch - 2020] (Guest)	22/9/23, 4:47:26 pm
129	Maroi [B.Arch - 2020] (Guest)	22/9/23, 5:53:49 pm
130	Guest	22/9/23, 4:51:12 pm
131	Guest	22/9/23, 5:03:30 pm
132	Bhavesh Khemka [B ARCH - 2021]	22/9/23, 4:51:41 pm
133	Kartik Gehlot [B ARCH - 2021]	22/9/23, 4:51:56 pm
134	Vaishnavi Shukla [B Arch - 2021]	22/9/23, 4:52:02 pm
135	Vaishnavi Shukla [B Arch - 2021]	22/9/23, 5:55:09 pm
136	abhijeet yadav (Guest)	22/9/23, 4:52:08 pm
137	Guest	22/9/23, 4:52:10 pm
138	Guest	22/9/23, 5:43:28 pm
139	Pranat Kothari [B.Arch - 2022]	22/9/23, 4:52:35 pm
140	Pranat Kothari [B.Arch - 2022]	22/9/23, 4:56:01 pm
141	Pranat Kothari [B.Arch - 2022]	22/9/23, 4:56:02 pm
142	Pranat Kothari [B.Arch - 2022]	22/9/23, 5:11:53 pm
143	[BARCH-001-2023-24] TANMAY GUPTA	22/9/23, 4:52:38 pm
144	Guest	22/9/23, 4:52:40 pm
145	Guest	22/9/23, 5:04:16 pm
146	Vanshika Chandel [B-ARCH - 2019]	22/9/23, 4:53:06 pm
147	Vanshika Chandel [B-ARCH - 2019]	22/9/23, 5:25:50 pm
148	Neha Saxena [MU - Jaipur]	22/9/23, 4:53:29 pm
149	Neha Saxena [MU - Jaipur]	22/9/23, 5:32:57 pm
150	Guest	22/9/23, 4:53:30 pm
151	Guest	22/9/23, 4:54:38 pm
152	Guest	22/9/23, 4:50:29 pm
153	Guest	22/9/23, 5:46:48 pm
154	Sajal Panwar [B.Arch - 2022]	22/9/23, 4:54:10 pm
155	Sajal Panwar [B.Arch - 2022]	22/9/23, 4:54:19 pm
156	Sajal Panwar [B.Arch - 2022]	22/9/23, 4:50:57 pm
157	Sajal Panwar [B.Arch - 2022]	22/9/23, 5:13:19 pm
158	Sajal Panwar [B.Arch - 2022]	22/9/23, 5:13:45 pm
159	Sajal Panwar [B.Arch - 2022]	22/9/23, 5:13:58 pm
160	Sajal Panwar [B.Arch - 2022]	22/9/23, 5:10:12 pm
161	Sajal Panwar [B.Arch - 2022]	22/9/23, 5:51:12 pm
162	Khushi Vipulkumar Chaudhari [B ARCH - 2021]	22/9/23, 4:55:09 pm
163	Khushi Vipulkumar Chaudhari [B ARCH - 2021]	22/9/23, 5:41:56 pm
164	Aishwarya Singh Rathore [B Arch - 2021]	22/9/23, 4:55:12 pm
165	Aishmeen Kaur [B ARCH - 2021]	22/9/23, 4:55:32 pm
166	Aishmeen Kaur [B ARCH - 2021]	22/9/23, 5:15:44 pm
167	Naveen Sharma	22/9/23, 4:58:39 pm
168	Guest	22/9/23, 4:59:12 pm
169	Guest	22/9/23, 5:29:55 pm
170	Guest	22/9/23, 5:03:45 pm
171	Guest	22/9/23, 5:26:59 pm
172	Harsh Shrivastav [B.Arch - 2021]	22/9/23, 5:05:52 pm
173	Harsh Shrivastav [B.Arch - 2021]	22/9/23, 5:08:09 pm
174	Arghya B S Bhagwat [B.Arch - 2022]	22/9/23, 5:07:24 pm
175	Aarya Chandiramani [B.Arch - 2022]	22/9/23, 5:08:13 pm
176	Aarya Chandiramani [B.Arch - 2022]	22/9/23, 5:28:08 pm

10.Weblink:

https://jaipur.manipal.edu/content/dam/manipal/muj/fod/Document/eventlist/EDP%20ON%20Bamboo%20-Event%20report.pdf

11.Event Coordinators:

- Ar. Sanjeev Pareek (Assistant Professor, SA&D)

  Ar. Kinzalk Chauhan (Assistant Professor, SA&D)

MANIPAL UNIVERSITY
JAIPUR

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MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENT'S WELFARE

(SOCIETY CONNECT)

And

Faculty of Science

Department of Chemistry

Presents

Plantation Drive

OCTOBER 26, 2023

Venue : Dabar Ki Dhani

1. **Introduction of the Event**

School of Basic science in collaboration with Directorate of Student Welfare, NCC, NSS organized a "Plantation Drive" on October 26, 2023. The societal connect outreach activity on by planting the small plants. Program is organized by the Department of Chemistry in collaboration with Department of Student welfare (DSW) under the guidance of Mr. Hemant Kumar (Assistant Director, DSW), Dr. Rahul Shrivastava (Head, Department of Chemistry) and Dr Meenakshi Pilania (Departmental coordinator, DSW). The mention activity held at a Government School, Dabar ki Dhani, near Manipal University Jaipur on Thursday, 26th October 2023.

2. **Objective of the Event**

The focal point of this event was to spread awareness among school students with respect to their environment and also motivate the students towards to work their endeavors via the power of knowledge and education.

3. **Beneficiaries of the Event**

Through this initiative, students and villagers had better communication and understanding of the situation.

4. **Details of the Guests**

The event was laid by the students of BBA, BBA(BA), IMBA

Rotary Club Jaipur Bapu Nagar

Rotary started with the vision of one man — Paul Harris. The Chicago attorney formed the Rotary Club of Chicago on 23 February 1905, so professionals with diverse backgrounds could exchange ideas and form meaningful, lifelong friendships.

Over time, Rotary's reach and vision gradually extended to humanitarian service. Members have a long track record of addressing challenges in their communities and around the world.

Rotary is a global network of 1.4 million neighbors, friends, leaders, and problem-solvers who see a world where people unite and take action to create lasting change – across the globe, in our communities, and in ourselves. They provide service to others, promote integrity, and advance world understanding, goodwill, and peace through our fellowship of business, professional, and community leaders. We collaborate with community leaders who want to get to work on projects that have a real, lasting impact on people's lives. We connect passionate people with diverse perspectives to exchange

ideas, forge lifelong friendships, and, above all, take action to change the world.

5. Brief Description of the event

The Department of Chemistry organized a societal connect outreach activity on Plantation in collaboration with the Department of Student Welfare (DSW) under the supervision of Mr. Hemant Kumar (Assistant Director, DSW), Dr. Rahul Shrivastava (Head, Department of Chemistry) and Dr. Meenakshi Pilania (Departmental coordinator, DSW). The mentioned activity was held at a Govt. school, Dabar ki Dhani, near Manipal University Jaipur on Thursday, 26th October 2023.

6. Photographs

Image 1 : Students with faculty at School for the Career Awareness

Image 2: Students of school during the plantation drive

Image 3: Team of MUJ Students at DABAR ki Dani School

7. Brochure or creative of the event

8. Schedule of the Event

The event took place on October 26, 2023

9. Attendance of the Event (50)

S. No.	Name	Registration No	Name of Institution
1	Rakshanda Singhal	211051012	Manipal University Jaipur
2	Vartika Vaishya	211051015	Manipal University Jaipur
3	Shakir Sisodia	201022604	Manipal University Jaipur
4	Govind Gupta	170703601	Manipal University Jaipur
5	Kanika Taneja	211004002	Manipal University Jaipur
6	Avani Kothari	221004004	Manipal University Jaipur
7	Pranjalee Ghosh	221004002	Manipal University Jaipur
8	Kishika Arora	221004003	Manipal University Jaipur
9	Aman Kumar	221004001	Manipal University Jaipur

10	Khushi Verma	211004006	Manipal University Jaipur
11	Karunya Papney	211004004	Manipal University Jaipur
12	Ankita Kumawat	211004003	Manipal University Jaipur
13	Supriyo	23FS20MCH00004	Manipal University Jaipur
14	Anjali Yadav	23FS20MCH00001	Manipal University Jaipur
15	Divya Sharma	23FS20MCH00003	Manipal University Jaipur
16	Vaibhav Anand	221013001	Manipal University Jaipur
17	Dipesh Gehlot	221013002	Manipal University Jaipur
18	Suman Yadav	221013003	Manipal University Jaipur
19	Ashish Sharma	221013004	Manipal University Jaipur
20	Ishan Jain	229310159	Manipal University Jaipur
21	Ishika Jain	229310410	Manipal University Jaipur
22	Aditi Singh Parihar	219311171	Manipal University Jaipur
23	Utkarsh Shukla	229301763	Manipal University Jaipur
24	Vedika	221007014	Manipal University Jaipur
25	Honey Trivedi	229302207	Manipal University Jaipur
26	Shaurya Nandwani	229301726	Manipal University Jaipur
27	Shreyas Bhati	229301374	Manipal University Jaipur
28	Aditya Mishra	229310237	Manipal University Jaipur
29	Aaryan kale	229303031	Manipal University Jaipur
30	Mustansir kanchwala	220903021	Manipal University Jaipur
31	Sahil Kalra	229303321	Manipal University Jaipur
32	Krishang Goel	229309035	Manipal University Jaipur
33	Anand Mandlik	229310162	Manipal University Jaipur
34	Aryan Sachdeva	229301438	Manipal University Jaipur
35	Ansh manawat	229301712	Manipal University Jaipur
36	Utkarsh Jha	220901009	Manipal University Jaipur
37	ria chauhan	229301253	Manipal University Jaipur
38	Ishita Sharma	229303237	Manipal University Jaipur
39	Ajinkya wagh	229310003	Manipal University Jaipur
40	Kritika Pahuja	229310048	Manipal University Jaipur
41	Ishan Aaditya	229303314	Manipal University Jaipur
42	Jiya Thakur	229309176	Manipal University Jaipur
43	Utsav Acharjya	229301358	Manipal University Jaipur
44	Kanishka Chaudhary	229202010	Manipal University Jaipur
45	Sameeksha	229310311	Manipal University Jaipur
46	Taarush Kathuria	229301462	Manipal University Jaipur
47	Ankit Kumar Tiwari	229309098	Manipal University Jaipur
48	Hanis Gori	229310131	Manipal University Jaipur
49	Aditya Prakash Sinha	229310189	Manipal University Jaipur
50	Lakshita Agrawal	229301455	Manipal University Jaipur

(Hemant Kumar)
Assistant Director, Society Connect
Directorate of Student's Welfare

(Prof. AD Vyas)
Director, Directorate of Student's Welfare

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

MANIPAL UNIVERSITY
JAIPUR

MUJ/Q&C/021/F/1.01

MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENT'S WELFARE

(SOCIETY CONNECT)

And

Faculty of Management and Commerce

Department of Business Administration

Presents

SWACH BHARAT

OCTOBER 25, 2023

1. **Introduction of the Event**

School of Business and Commerce in collaboration with Directorate of Student Welfare, Directorate of sports and NCC, NSS organized a "SWACH BHARAT" on October 25, 2023. 52 students participated in the campaign. The event took place in Dehmi Kalan hamlet.

2. **Objective of the Event**

The aim of the campaign was to raise awareness about Waste Segregation and encourage education on the SWACH BHARAT.

3. **Beneficiaries of the Event**

Through this initiative, students and villagers had better communication and understanding of the situation.

4. **Details of the Guests**

The event was laid by the students of BBA, BBA(BA), IMBA

Rotary Club Jaipur Bapu Nagar

Rotary started with the vision of one man — Paul Harris. The Chicago attorney formed the Rotary Club of Chicago on 23 February 1905, so professionals with diverse backgrounds could exchange ideas and form meaningful, lifelong friendships.

Over time, Rotary's reach and vision gradually extended to humanitarian service. Members have a long track record of addressing challenges in their communities and around the world.

Rotary is a global network of 1.4 million neighbors, friends, leaders, and problem-solvers who see a world where people unite and take action to create lasting change – across the globe, in our communities, and in ourselves. They provide service to others, promote integrity, and advance world understanding, goodwill, and peace through our fellowship of business, professional, and community leaders. We collaborate with community leaders who want to get to work on projects that have a real, lasting impact on people's lives. We connect passionate people with diverse perspectives to exchange ideas, forge lifelong friendships, and, above all, take action to change the world.

5. **Brief Description of the event**

The event was initiated to make students aware of their surroundings with respect to Waste and it consequences on the local community. The students went on a rally in groups, holding posters on Wet Waste and Dry Waste. They were chanting slogans "Alag Karo Alag Karo" Gila aur Sukha Kachara Alag Karo, to make the local community aware of the Waste Segregation process.

6. Photographs

Image 1 : Students with faculty

Image 2: Students walking with the Rally through the Village

Image 3: Team of MUJ Students at Village for Rally

Image 4: Team of MUJ Students at Village for Rally

7. Brochure or creative of the event

8. Schedule of the Event

The event took place on Ocotber 25, 2023

9. Attendance of the Event

Sr. No	Name of Institution	Registration No	Attendee Name
1	Manipal University Jaipur	23FM10BBA00122	Naresh Choudhary
2	Manipal University Jaipur	23FM10BBA00123	Prem Singhrathore
3	Manipal University Jaipur	23FM10BBA00124	Yash Vardhansingh
4	Manipal University Jaipur	23FM10BBA00125	Krishna Snair
5	Manipal University Jaipur	23FM10BBA00126	Viyom Gupta
6	Manipal University Jaipur	23FM10BBA00127	Aditya Singh shekhawat
7	Manipal University Jaipur	23FM10BBA00128	Sheikh Tabish ahmed
8	Manipal University Jaipur	23FM10BBA00129	Bhavesh Aggarwal
9	Manipal University Jaipur	23FM10BBA00130	Riddhima Gupta
10	Manipal University Jaipur	23FM10BBA00131	Ishita Sharma
11	Manipal University Jaipur	23FM10BBA00132	Akshat Sharma
12	Manipal University Jaipur	23FM10BBA00133	Preksha Sood
13	Manipal University Jaipur	23FM10BBA00134	Tanisha Agarwal
14	Manipal University Jaipur	23FM10BBA00135	Ram Avtarchouhan

15	Manipal University Jaipur	23FM10BBA00136	Sourabh Shekhawat
16	Manipal University Jaipur	23FM10BBA00137	Abhishek Jain
17	Manipal University Jaipur	23FM10BBA00138	Priyanshu Yadav
18	Manipal University Jaipur	23FM10BBA00139	Riddhi Charan
19	Manipal University Jaipur	23FM10BBA00140	Akhil
20	Manipal University Jaipur	23FM10BBA00141	Shaily Kushwaha
21	Manipal University Jaipur	23FM10BBA00142	Deep Mittal
22	Manipal University Jaipur	23FM10BBA00143	Rahul Choudhary
23	Manipal University Jaipur	23FM10BBA00144	Ronil Joshi
24	Manipal University Jaipur	23FM10BBA00145	Arihant Jaisawal
25	Manipal University Jaipur	23FM10BBA00146	Ayush Kumarthakur
26	Manipal University Jaipur	23FM10BBA00147	Angad Yadav
27	Manipal University Jaipur	23FM10BBA00148	Shashank Chaudhary
28	Manipal University Jaipur	23FM10BBA00149	Khushi Gupta
29	Manipal University Jaipur	23FM10BBA00150	Garvita Rathore
30	Manipal University Jaipur	23FM10BBA00151	Anirban Bhattacharyya
31	Manipal University Jaipur	23FM10BBA00152	Keshav Badthuniya
32	Manipal University Jaipur	23FM10BBA00153	Yash Saini
33	Manipal University Jaipur	23FM10BBA00154	Vineet Kumar
34	Manipal University Jaipur	23FM10BBA00155	Bhavuk Parashar
35	Manipal University Jaipur	23FM10BBA00156	Mohit Oshu
36	Manipal University Jaipur	23FM10BBA00157	Honey Chandnani
37	Manipal University Jaipur	23FM10BBA00158	Veer Singh
38	Manipal University Jaipur	23FM10BBA00159	Naman Kriplani
39	Manipal University Jaipur	23FM10BBA00160	Himanshu Yogesh Mittal
40	Manipal University Jaipur	23FM10BBA00161	Amogh Goyal
41	Manipal University Jaipur	23FM10BBA00162	Alina Nadeem
42	Manipal University Jaipur	23FM10BBA00163	Prince Gandhi
43	Manipal University Jaipur	23FM10BBA00164	Devansh Devansh Tiwari
43	Manipal University Jaipur	221016048	Aarohi
44	Manipal University Jaipur	229301387	Soham maskara
45	Manipal University Jaipur	229301650	Karan Kapoor
46	Manipal University Jaipur	229301552	MONIL SHAH
47	Manipal University Jaipur	229311009	Krittika Wadhawan
48	Manipal University Jaipur	229301034	Maulik Mehrotra
49	Manipal University Jaipur	229302340	Shreya Saihgal
50	Manipal University Jaipur	229302257	Yash Dhruv
51	Manipal University Jaipur	229302641	Pankaj Patel
52	Manipal University Jaipur	229310250	Amrit Raj
53	Manipal University Jaipur	220901154	Mehul rawat
54	Manipal University Jaipur	221201002	Palak chawla
55	Manipal University Jaipur	229309070	Pranav Banker
56	Manipal University Jaipur	229303128	Mahi Bhardwaj
57	Manipal University Jaipur	229303305	Karshh Divekar
58	Manipal University Jaipur	229310242	Ashmit

59	Manipal University Jaipur	229301681	Armaan Deep Singh Bedi
60	Manipal University Jaipur	229302281	Shriyam Singh Tiwari
61	Manipal University Jaipur	229301130	Shreyansh Reddy
62	Manipal University Jaipur	220901032	Raj Singh
63	Manipal University Jaipur	211103077	Sanmai Pathak
64	Manipal University Jaipur	211103075	Anvesha Shekhar
65	Manipal University Jaipur	219311129	Shubham Yadav
66	Manipal University Jaipur	221201033	Divanshi Gupta
67	Manipal University Jaipur	229310052	Lakshya Khandelwal
68	Manipal University Jaipur	229303191	Krishang Shukla
69	Manipal University Jaipur	221305050	Baibhav Bhanu Naithani
70	Manipal University Jaipur	229302371	Rishika Bhagawati
71	Manipal University Jaipur	229311168	Rudra Nayyar
72	Manipal University Jaipur	229311024	Shivam Singh
73	Manipal University Jaipur	229311289	puneet more
74	Manipal University Jaipur	229310200	Nainish Mane
75	Manipal University Jaipur	229310153	Diksha M
76	Manipal University Jaipur	221007068	Akshita Pandey
77	Manipal University Jaipur	229309068	Rahul Trivedi
78	Manipal University Jaipur	229309052	Raeez Mohammed K P

Dr Narendra Singh Bhati HoD, BBA

(Hemant Kumar)
Assistant Director, Society Connect
Directorate of Student's Welfare

(Prof. AD Vyas)

Director, Directorate of Student's Welfare

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

MANIPAL UNIVERSITY JAIPUR

FACULTY OF ARTS

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF ARTS

Tree plantation Drive

Social outreach event in collaboration with DSW and NCC

06/09/2023

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1. Introduction of the Event
2. Objective of the Event
3. Beneficiaries of the Event
4. Details of the Guests
5. Brief Description of the event
6. Geo-tagged Photographs
7. Brochure or creative of the event
8. Schedule of the Event
9. Attendance of the Event
10. News Publication
11. Feedback of the Event
12. Link of MUJ website

1. **Introduction of the Event**
   The Department of Arts in collaboration with the DSW (NCC and NSS) organized a tree plantation drive with a number of BA(Liberal Arts) students.

2. **Objective of the Event (bullet points or about 50 words)**

To make the students aware of the importance of tree plantation.

3. **Beneficiaries of the Event**

   Government school, Begas, an adopted school of MUJ

4. **Brief Description of the event**
   The Department of Arts in collaboration with the DSW (NCC and NSS) organized a tree plantation drive with a number of BA(Liberal Arts) students. The objective of the event was to make the students aware of the importance of tree plantation.

5. Photographs

Students engaged in a tree plantation drive in the government school, Begas

GPS Map Camera
Begas, Rajasthan, India
VHF2+FP2, Begas, Rajasthan 303007, India
Lat 26.873903°
Long 75.552877°
06/09/23 11:26 AM GMT +05:30
Google

MUJ students with the government school students

MUJ department students during the plantation drive

6. Brochure or creative of the event (insert in the document only)

8x4.5 feet

7. Schedule of the event (insert in the report)

6th September, 11:00 a.m. to 12:00 p.m.

8. Attendance of the Event (insert in the document only)
Total attendee-16

Sr. No	Name of Institution	Place of Institution	Name of Attendee	Name of Dept
1.	MUJ	Jaipur	Chandravardhan	Arts
2.	MUJ	Jaipur	Kumesh Mishra	Arts
3.	MUJ	Jaipur	Soumya Pareek Dhanushree	Arts
4.	MUJ	Jaipur		Arts
5.	MUJ	Jaipur	Karan Mallick	Arts
6.	MUJ	Jaipur	Vanshika Agarwal	Arts
7.	MUJ	Jaipur	Prithviraj	Arts
8.	MUJ	Jaipur	Akshatt Singh	Arts
9.	MUJ	Jaipur	Dhruv Nair	Arts
10.	MUJ	Jaipur	Krishna	Arts
11.	MUJ	Jaipur	Gaury	Arts
12.	MUJ	Jaipur	Sudeepti Dhruv Dahiya	Arts
13.	MUJ	Jaipur	Aditi Panigrahi	Arts
14.	MUJ	Jaipur	Aradhya Khandelwal	Arts
15.	MUJ	Jaipur	Komal Chadha	Arts
16.	MUJ	Jaipur	Krritika Khandelwal Pragya Sharma	Arts
17.	MUJ	Jaipur	Prachi Randhawa	Arts
18.	MUJ	Jaipur	Gurmehr Singh	Arts
19.	MUJ	Jaipur	Himmat di Charan	Arts
20.	MUJ	Jaipur	Sameer Khan	Arts
21.	MUJ	Jaipur	Ananya Thakur	Arts
22.	MUJ	Jaipur	Harshita Das	Arts
23.	MUJ	Jaipur	Manan Sharma	Arts

24.	MUJ	Jaipur	Surendra Singh	Arts
25.	MUJ	Jaipur	Joy Tak	Arts
26.	MUJ	Jaipur	Soumya harma	Arts
27.	MUJ	Jaipur	Deepak	Arts
28.	MUJ	Jaipur	Anup Choudhary	Arts
29.	MUJ	Jaipur	Prithviraj Hada	Arts
30.	MUJ	Jaipur	Tanisha Vashisht	Arts

9. Link of MUJ website stating the event is uploaded on website

https://jaipur.manipal.edu/muj/news-events/events-list.html

Dr. Mani Sachdev
Head, Department of Arts
Manipal University Jaipur

15.9.23

Seal and Signature of HOD

MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

SCHOOL OF ARCHITECTURE AND DESIGN

FACULTY OF DESIGN

05-Day Online Faculty Development Program in collaboration with CoA TRC, Bhopal

on

‘Rethinking Building Byelaws & Planning Regulations’

Online : Zoom

23rd - 27th January 2023

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1. Introduction of the Program:

Building Byelaws play an important role in building design and its execution. Environmental cause, social aspects and economic processes have caused a significant shift in architectural thinking during the past few decades. It becomes important to impart the related knowledge regarding building byelaws and their sustenance over the time.

This program is an effort to provide an in-depth understanding of emerging scenarios and concepts related to building design and urban development. This FDP shall offer a platform to discuss the imperatives of building byelaws and regulations with respect to role of Urban Local Bodies paving way to crop solutions and guidelines particularly in Indian context.

The participants will be able to comprehend the change in thought process for a more optimum use of land and development under the impact of changing environmental, social, economic and political scenarios.

Hence, School of Architecture and Design, MUJ in collaboration with Council of Architecture, Training and Research Centre, Bhopal organized and conducted a 5-day online Faculty development program on **Rethinking Building Byelaws & Planning Regulations** from **23rd – 27th January 2023.**

2. Objectives of the Workshop:

- To impart knowledge about contextual understanding, sustainability, inclusivity, safety and security, functionality, cost-effectiveness, and aesthetic appeal within the regulatory realm.
- To encourage participants for implementing this knowledge while designing cities & buildings to achieve sustainability and cultural & heritage conservation.
- To enable participants in delivering quality, managing risks, and nurturing innovation to allow for maximized public interest of investment for the built environment.

3. Beneficiaries of the Event:

- Academicians
- Ph.D. Scholars
- Policy makers from the Department of Town Planning & Development Authorities
- Professionals from the field of Building construction & allied fields.

The specific SDG that are incorporated in the event -

SDG 3: Ensure healthy lives and promote well-being for all at all ages, SDG 6: Ensure availability and sustainable management of water and sanitation for all SDG 9: Industry, Innovation, and Infrastructure, SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable, SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

4. Details of the Guests:

S.No.	NAME	DESIGNATION	TOPIC
1.	Ar. Shobhit Tayal	Architect Planner and Co-founder, Design and Planning Counsel	Enhancing the Quality of Life through Building Byelaws
2.	Prof. Anjali Sharma	Professor and Director, School of Architecture Planning and Design, DIT University	Building Byelaws – A tool for Preserving Image of the City
3.	Prof. Anand Khatri	Founding Director Urban Village Charitable Trust and Professor, AIT SAP	Critically Evaluating Building Bye-laws for Indian Cities: Academician Perspective
4.	Dr. Sandeep Sharma	Assistant Professor, Department of Architecture, National Institute of Technology, Hamirpur	Building Byelaws/Regulations for Resilience in India
5.	Ar. Mala Mohan	Retd. ADG (Arch), Military Engineering Service, Ministry of Defence	Building Byelaws for Healthcare Facilities
6.	Prof. (Dr.) Rajiv Mishra	Principal at Sir JJ college of Architecture, University of Mumbai	Reforms in Fire Code & Accessibility for all in Historic Buildings
7.	Prof. Jit Kumar Gupta	Founding Director COA, Bhaddal	Building Plan Approval Process and Systems.
8.	Dr. Shikha Jain	Founding Director, DRONAH	Heritage Bye Laws for Built & Natural sites
9.	Dr. Pawan Kumar	Associate Town and Country Planner in TCPO, New Delhi	Building Byelaws and Planning Practices in Hilly Region
10.	Dr. Monalisa Bhardwaj	Associate Professor at the Department of Architecture, Ramaiah Institute of Technology, Bangalore	Urban Design Development - Laws and guidelines in India.

5. Brief Description of the event:

The 5-day online Faculty Development Program on Rethinking Building Byelaws & Planning Regulations started with an inaugural & welcome by Hon. Director, CoA TRC Bhopal along with Dr. Madhura Yadav (Professor, Architecture and Dean, FoD) Chief Coordinator, Ar. Neha Saxena (Asso. Prof.) and Ar. Ayushi Sharma (Asst. Prof.), School of Architecture and Design, Manipal University Jaipur.

A summary of the sessions by all experts is as follows:

1. **Ar. Shobhit Tayal: Enhancing the Quality of Life through Building Byelaws**

According to Ar. Shobhit Tayal, the quality of life directly related to infrastructure of the place. A good infrastructure can be provided when we as professionals are continuously aiming for better progressive byelaws through practicing transparency in developing permissions and approvals. He also suggested, through examples of good initiative like Rajkot, the potential possibilities of revamping the zoning and special regulations and how the built form and public plazas in

commercial zones must be envisaged. Ar. Tayal aptly pointed out the myths that people relate to quality of life with built environment, density and building and FAR and building height relation and concluded that the same must be relative to land and building use.

2. Prof. Anjali Sharma: Building Byelaws – A tool for Preserving Image of the City

After having understood that the fire codes and norms do not mandatorily exist for the heritage buildings, due to which we have witnessed us some shocking and unfortunate incidents that have occurred in the last few years, which can be resolved using the context based byelaws.

She enlightened us with many ways that can be integrated and used by us professionals on how these byelaws can be integrated in the heritage context as well as for other built forms, along with the cooperation of urban local bodies Professor highlighted on the need of the hour to make the byelaws inclusive as per the image of the city with respect to all the stages of the project with distinctive regard to the immediate and local context.

She provokes each one of us to rethink our personal takes to make conscious efforts to deliver definite values, and to enhance the quality of life through building byelaws.

3. Prof. Anand Khatri: Critically Evaluating Building Bye-laws for Indian Cities: Academician Perspective

Prof. Anand Khatri initiated with explaining the development scenarios of cities, which helped us understand the changing dynamics with respect to both land values and ecology. He threw bright light on the subject of the new concept of ecological acquisition, which we need to look into carefully, as there are certain subject areas that need attention at city level, while others at a local or contextual level.

Therefore, in his perspective, we must all find means to take conscious steps towards formulating synergies between the urban formalities and informalities, and to not push out the urban informalities out of the city development strategies.

4. Dr. Sandeep Sharma: Building Byelaws/Regulations for Resilience in India

Dr. Sandeep Sharma initiated his talk with briefing about the comprehensive revisions and features that have been included in building byelaws and regulations in 2016 like Green Buildings, structural safety, high rise buildings, Swatchh Bharat Mission, Rain Water Harvesting, communication & technology, conservation of heritage sites and ease of building plan approvals through single window processes. He elaborated on various features through specific examples of hilly regions and states of India. According to him, byelaws must be resilient enough to correspond to the natural or man made disasters. Through his comparative analysis, he emphasized that regulations must be formulated to be region specific based on climate, topography and orientation, etc. He further stressed on the importance to establish minimum standards for building regulations for acceptable performance.

5. Ar. Mala Mohan: Building Byelaws for Healthcare Facilities

The importance of each and every factor that is involved in the designing and planning of a healthcare facilities, ranging from its site area to programming was explained in great detail. From smallest of details such as of corridor widths to ramps, each plays a crucial role in the functioning of a good hospital.

On the contrary, even in today's date these important details are not being paid the required attention and thought, as it is our moral duty to play our responsible roles in this regard, especially when it comes to healthcare facilities, be it in rural or urban setups.

6. Prof. (Dr.) Rajiv Mishra: Reforms in Fire Code & Accessibility for all in Historic Buildings

Through his expertise in heritage conservation, Prof. Rajiv Mishra shed light on reforms in fire code and accessibility that are a need of the hour for historic buildings. By Supreme Court Law, compliance with fire safety and accessibility is a mandate and it is the responsibility of professionals like us to do it sensitively. This shall enable a historic building to live by itself in the current scenario. He concluded by suggesting ways forward and roles of both practicing architects and academicians to sensitize the public as well as authorities to pay attention towards preserving our heritage.

7. Prof. Jit Kumar Gupta: Building Plan Approval Process and Systems

It is surprising to observe that even till date, the entire system of codes and regulations in India still remains complex in India. Our key role still remains to reduce the conflicts between the manmade and natural environments, as buildings have direct relations with human beings, their well being, health, external environment and other such factor. Henceforth, making it very important for us to have an in depth understanding of codes, norms, byelaws and regulations.

The changing typologies make buildings more susceptible to all kinds of damages and disasters, hence working in an exhaustive and extensive process will help us through all the stages of building design, till its approval which is one of the toughest stage, till its execution.

8. Dr. Shikha Jain: Heritage Bye Laws for Built & Natural sites

According to Dr. Shikha Jain different government authorities and private organizations are facing challenges for Heritage Management of our cultural heritage. Through, key highlights from Report on developing Research Project Database for Niti Aayog, as prepared by her organization DRONAH, she pointed out that from about 500000 heritage properties identified, only 10% have the status of being protected by central or state authorities. In this process, however, a paradigm shift has been observed on part of organizations, public and experts and they are taking dynamic initiatives towards listing and protecting our heritage. This is also setting an example for those who are still unaware or hesitant towards the noble cause.

9. Dr. Pawan Kumar: Building Byelaws and Planning Practices in Hilly Region

Dr. Pawan through his presentation has raised a concern on the critical conditions and challenges faced by hilly regions that need immediate attention and action. He emphasized that although there are many policies, regulations and bye laws in place, the same need to be upgraded to address the current concerns. For this, there needs to be a synergy amongst different agencies, departments and public both tourists and local communities. He also shared prevailing good practices and solutions that are happening as small initiatives locally and globally and according to him it is the need of the hour to incorporate these practices as part of local bye laws and regulations.

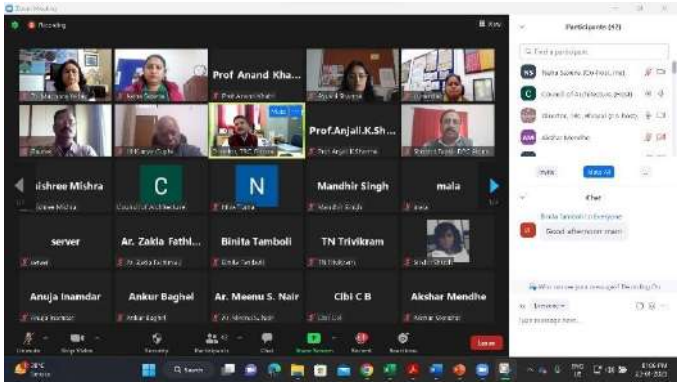
10. Dr. Monalisa Bhardwaj: Urban Design Development – Laws and Guidelines in India

Through her presentation Dr. Monalisa emphasized the importance of understanding the existing provisions and laws within the constitution of India. She mentioned that both tangible and

intangible aspects are already embedded in the constitution which need to be understood and implemented. While, the vision travels bottom to up, the approvals travel top to bottom, hence the complexity of processing needs to be realized. She also gave an overview of policies and roles of institution at different hierarchical levels and the interface between the urban and the rural. She quite clearly explained how policies translate into the Urban undertakings and illustrated the outcomes through examples.

The event concluded with a valedictory session and thanking all the experts and participants for their time and dedication. On the last day, an online MCQ and feedback form was circulated to all participants as a mandate (by CoA TRC, Bhopal) for receiving certificates for attending the five day online program. The event received overwhelming response from the participants and appreciation by CoA TRC, Bhopal for SA&D, MUJ as host institute.

6. Screenshots of the event:



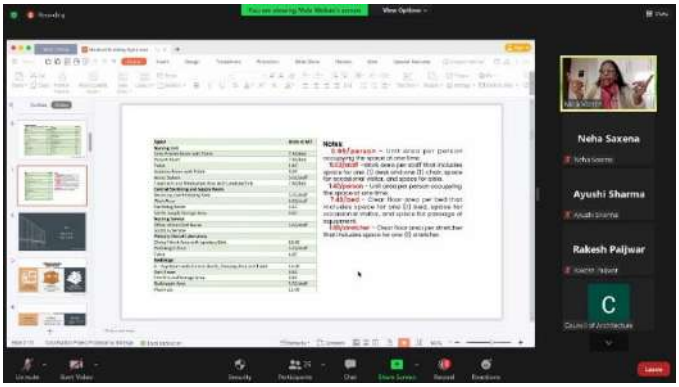
1. *Inaugural Address by Hon. Director, CoA TRC, Bhopal and Prof. (Dr.) Madhura Yadav, Dean, FoD*

2. *Session by Ar. Shobhit Tayal – Day 1 Session 1*

3. *Session by Prof. Anjali Sharma – Day 1 Session 2*

4. *Session by Prof. Anand Khatri – Day 2 Session 1*

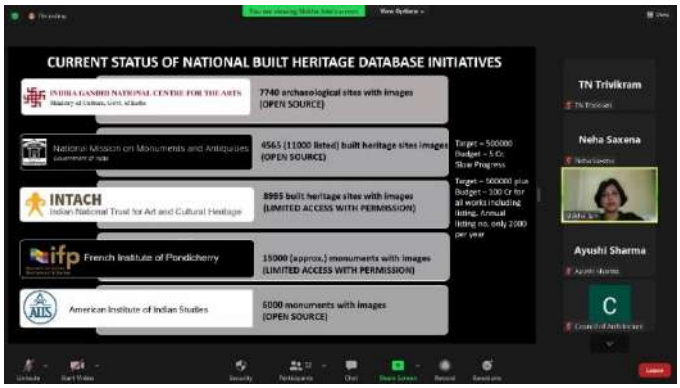
5. *Session by Dr. Sandeep Sharma – Day 2 Session 2*



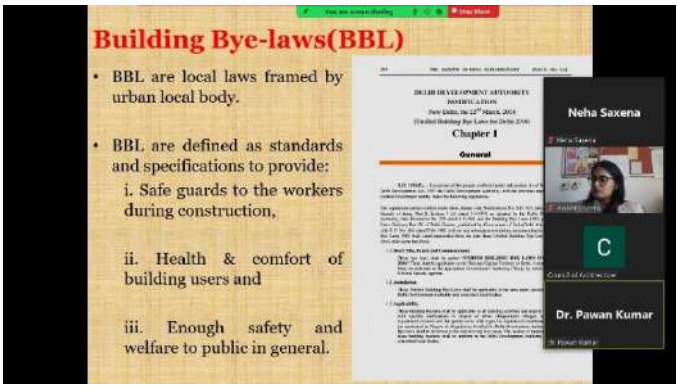
6. *Session by Ar. Mala Mohan – Day 3 Session 1*

7. Session by Prof. Rajiv Mishra – Day 3 Session 2

8. Session by Prof. Jit Kumar Gupta – Day 4 Session 1



1. Session by Dr. Shikha Jain – Day 4 Session 2

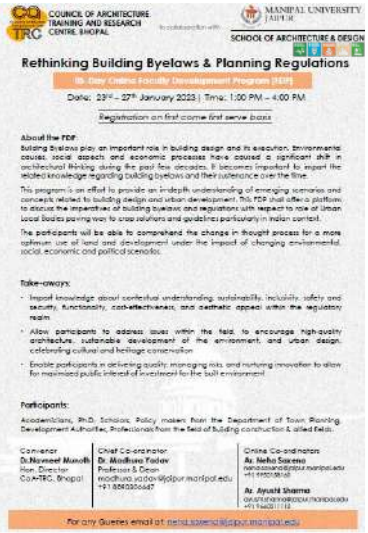


2. Session by Dr. Pawan Kumar – Day 5 Session 1

3. Session by Dr. Monalisa Bhardwaj – Day 5 Session 2

4. Valedictory Session with the participants and experts

7. Brochure of the event:



8. Schedule of the event

Day 1	12:45 pm - 1:00 pm	1:00 pm -2:30 pm	2:30 pm – 4:00 pm
23/01/2023 (Monday)	Inauguration	Session – 01	Session – 02
		Ar. Shobhit Tayal	Prof.Anjali Sharma
Day 2	12:45 pm - 1:00 pm	1:00 pm -2:30 pm	2:30 pm – 4:00 pm
24/01/2023 (Tuesday)	Day briefing	Session – 03	Session – 04
		Prof. Anand Khatri	Dr. Sandeep Sharma
Day 3	12:45 pm - 1:00 pm	1:00 pm -2:30 pm	2:30 pm – 4:00 pm
25/01/2023 (Wednesday)	Day briefing	Session – 05	Session – 06
		Ar. Mala Mohan	Prof. (Dr.) Rajiv Mishra
Day 4	12:45 pm - 1:00 pm	1:00 pm -2:30 pm	2:30 pm – 4:00 pm
26/01/2023 (Thursday)	Day briefing	Session – 07	Session – 08
		Prof. Jit Kumar Gupta	Dr. Shikha Jain

Day 5	12:45 pm - 1:00 pm	1:00 pm -2:30 pm	2:30 pm – 4:00 pm	4:00 pm – 4:15 pm
27/01/2023 (Friday)	Day briefing	Session – 09	Session – 10	Valedictory
		Dr. Pawan Kumar	Dr. Monalisa Bhardwaj	

9. Registration Details:

S No	Name	Email	Phone Number	Institute/ College Code	City
1	Akshar Mendhe	aksharmendhe.scoa@sinhgad.edu	9511277059	MH 33	Pune
2	Ankur Baghel	ankur.11090@gmail.com	9752388921	OR 08	Rourkela
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16	Mandhir Singh	msrathore3663@gmail.com	9780463293	PJ03	Punjab (S.A.S Nagar)
17	Meenu S Nair	meenus.nair@reva.edu.in	9848121102	KA 36	Bangalore
18	Mohammed Waseem Akram	mdwaseemakram.arch@drmgrdu.ac.in	9962798479	TN41	Chennai
19	Naveena Verma	naveena.verma@chitkara.edu.in	7340775288	PJ04	Rajpura
20	Nayruti Mistry	nayrutimistry@gmail.com	9909368760	Gujarat Infrastructure Development Board	Gandhinagar
21	Niva Turna	niva.turna@chitkara.edu.in	9855088873	PJ04	Rajpura
22	PULKIT GUPTA	drpulkitgupta4u@gmail.com	9829026790	RJ-02	Jodhpur
23	Rahul Kumar Rathore	rishabhrathore890@gmail.com	7898655223	MP01	Bhopal
24	Rajesh Sharma	123rsa@gmail.com	9414294164	RJ-02	JODHPUR
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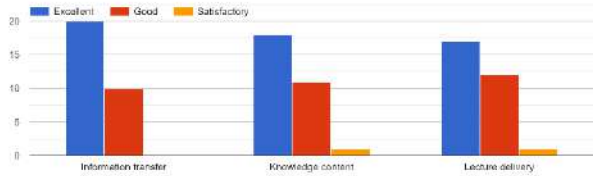
31	Sushmita.B	sushmita.arch@drmgrdu.ac.in	9790981919	TN41	CHENNAI
32	TN TRIVIKRAM	trivikram.tn@manipal.edu	7799892428	KA02	MANIPAL
33	Vedhavalli Sathrusangaravel	Vedhavalli.arch@drmgrdu.ac.in	9789531100	TN41	Chennai
34	Zakia Fathima J	zakiafathima.arch@drmgrdu.ac.in	9789807543	TN41	Chennai
35	C.B.Cibi	cibi@psgitech.ac.in	8220222645	TN99	PSGIAP
36	Priyanka Mehta	arpriyankamehta@gmail.com	98290 26200	RJ02	Jodhpur

10. Attendance of the Event:

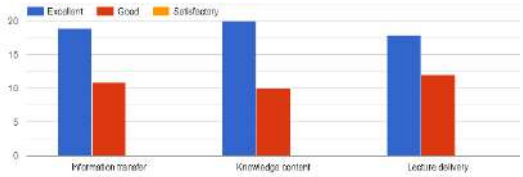
Day 1 - 44	Day 2 - 41	Day 3 - 38	Day 4 - 37	Day 5 - 38
Participants (44)	Participants (41)	Participants (38)	Participants (37)	Participants (38)
Find a participant	Find a participant	Find a participant	Find a participant	Find a participant
NS Neha Saxena (Co-host, me)	NS Neha Saxena (Co-host, me)	NS Neha Saxena (Co-host, me)	NS Neha Saxena (Co-host, me)	NS Neha Saxena (Co-host, me)
C Council of Architecture (Host)	C Council of Architecture (Host)	C Council of Architecture (Host)	C Council of Architecture (Host)	C Council of Architecture (Host)
Shobhit Tayal- DPC Ahmedabad	PA Prof Anand Khatri	P Prof.Anjali.K.Sharma	MM Mala Mohan	MB Monalisa Bhardwaj
Director, TRC, Bhopal (Co-host)	AS Ayushi Sharma (Co-host)	AM Akshar Mendhe	AS Ayushi Sharma (Co-host)	MI Monalisa iPhone
AM Akshar Mendhe	DM Dr. Madhura Yadav (Co-host)	AB Ankur Baghel	AB Ankur Baghel	AM Akshar Mendhe
AB Ankur Baghel	AM Akshar Mendhe	AK Antony Kumar Boity	AK Antony Kumar Boity	AB Ankur Baghel
AK Antony Kumar Boity	AB Ankur Baghel	AI Anuja Inamdar	AI Anuja Inamdar	AI Anshu's iPhone
AI Anuja Inamdar	AK Antony Kumar Boity	AM Ar. Meenu S. Nair	AP Ar. Pulkit Gupta	AI Anuja Inamdar
AM Ar. Meenu S. Nair	AI Anuja Inamdar	AM Ar.Bindu Malhotra	AZ Ar. Zakia Fathima J	AM Apeksha. M
AP Ar. Pulkit Gupta	AM Apeksha. M	AG AR.PULKIT GUPTA	AM Ar.Bindu Malhotra	AH Ar Holyna Annie Gifta G
AZ Ar. Zakia Fathima J	AM Ar. Meenu S. Nair	A Ar.Surander	BP Baishali Pradhan	AM Ar. Meenu S Nair
AM Ar.Bindu Malhotra	AP Ar. Pulkit Gupta	AS Ayushi Sharma	BT Binita Tamboli	AP Ar. Pulkit Gupta
AS Ayushi Sharma	AZ Ar. Zakia Fathima J	BP Baishali Pradhan	CC Cibi C B	AZ Ar. Zakia Fathima J
BP Baishali Pradhan	AM Ar.Bindu Malhotra	BT Binita Tamboli	DM Dr. Madhura Yadav	AM Ar.Bindu Malhotra
BT Binita Tamboli	A Ar.Harshini	CC Cibi C B	DS Dr.Rajesh Sharma	AS Ayushi Sharma
CC Cibi C B	A Ar.Surander	DA Dr. Anshu Agrawal	HB Harendra Bohra	BP Baishali Pradhan
DS Dr Sandeep Sharma	BP Baishali Pradhan	DM Dr. Madhura Yadav	H Harshini.G	BT Binita Tamboli
DA Dr. Anshu Agrawal	BT Binita Tamboli	DR Dr. RAJESH SHARMA	H Holyna Annie Gifta G	C Cibi
DM Dr. Madhura Yadav	CC Cibi C B	G Gaurav	JM Jaishree Mishra	DA Dr. Anshu Agrawal
DR Dr. RAJESH SHARMA	DS Dr Sandeep Sharma	HB Harendra Bohra	JC Jotirmay Chari	DM Dr. Madhura Yadav
G Gaurav	DA Dr. Anshu Agrawal	H HARSHINI	LW L.Ar.Mohammed Waseem Ak	DR Dr. RAJESH SHARMA
H Harshini	DR Dr. RAJESH SHARMA	H Holyna Annie Gifta G	MS Mandhir Singh	HB Harendra Bohra
H Holyna Annie Gifta G	HB Harendra Bohra	I iPhone	Meenu Nair	JM Jaishree Mishra
JM Jaishree Mishra	H Holyna Annie Gifta G	JM Jaishree Mishra	MA Ms. Apeksha Manjunath	JC Jotirmay Chari
JK Jit Kumar Gupta	JM Jaishree Mishra	JC JOTIRMAY CHARI	N naveena	MS Mandhir Singh
M mala	JC Jotirmay Chari	MS Mandhir Singh	N Niva Turna	N naveena
MS Mandhir Singh	MS Mandhir Singh	MA Ms. Apeksha Manjunath	R Rahul rathore	N naveena
MA Ms. Apeksha Manjunath	N NAYRUTI MISTRY	N naveena	RP Rakesh Paijwar	N NAYRUTI MISTRY
N naveena	N Niva Turna	N Niva Turna	RC Roopa Chikkalgi	NT Niva Turna
N Niva Turna	PM Priyanka Mehta	R Rahul rathore	SJ Shubham Jaiswal	RK Rahul Kumar Rathore
PA Prof Anand Khatri	R Rahul rathore	RC Roopa Chikkalgi	TT TN Trivikram	RP Rakesh Paijwar
P Prof.Anjali.K.Sharma	RP Rakesh Paijwar	SJ Shubham Jaiswal	V VEDHAVALLI	RC Roopa Chikkalgi
R Rahul rathore	RK Richa Kushwaha	Srishti Shubh	VS vedhavalli Sathrusangaravel	SJ Shubham Jaiswal
RC Roopa Chikkalgi	RC Roopa Chikkalgi	SI Sushmita's iPhone	A Ar.Surander	TT TN Trivikram
SJ Shubham Jaiswal	SJ Shubham Jaiswal	TT TN Trivikram	HA Holyna Annie Gifta G	VS vedhavalli Sathrusangaravel
Srishti Shubh	SS Srishti Shubh	HA Holyna Annie Gifta G		MW mohammed waseem akram
S sunandak	TT TN Trivikram	LW L.Ar.Mohammed Waseem Akram		PM Priyanka Mehta
TT TN Trivikram	VS vedhavalli Sathrusangaravel	V VEDHAVALLI		
V Vedhavalli	H HARSHINI			
A Ar.Surander				
HA Holyna Annie Gifta G				
PM priyanka mehta				

11. Feedback of the Event:

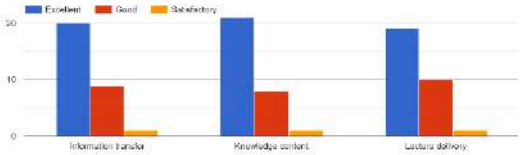
Day 1- Session 1: Enhancing the Quality of Life through Building Byelaws by Ar. Shobhit Tayal



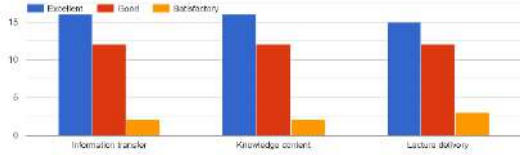
Day 1- Session 2: Building Byelaws A Tool for Preserving Image of the City by Prof. Anjali Sharma



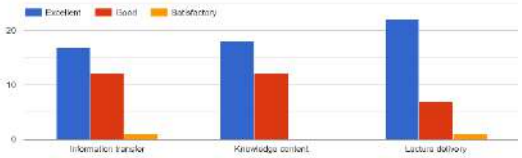
Day 2- Session 1: Critically Evaluating Building Bye laws for Indian Cities Academician Perspective by Prof. Anand Khatri



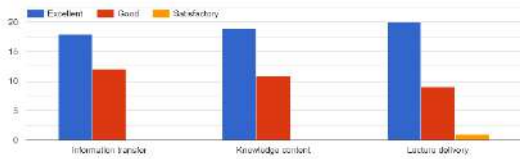
Day 2- Session 3: Building Byelaws/Regulations for Resilience in India by Dr. Sandeep Sharma



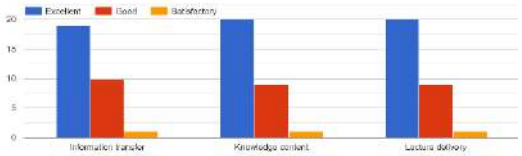
Day 3- Session 1: Building Byelaws for Healthcare Facilities by Ar. Mala Mohan



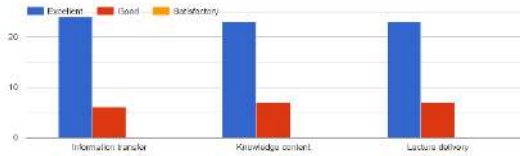
Day 3- Session 2: Reforms in Fire Code Accessibility for all in Historic Buildings by Prof. (Dr.) Rajiv Mishra



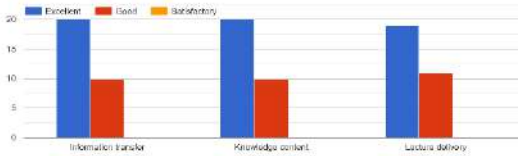
Day 4 - Session 1: Building Plan Approval Process and Systems by Prof. Jit Kumar Gupta



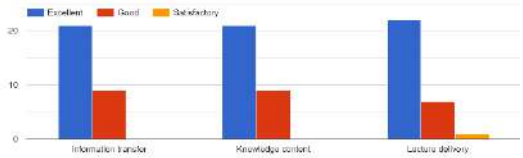
Day 4- Session 2: Heritage Bye Laws for Built & Natural sites by Dr. Shikha Jain



Day 5- Session 1: Role of Building Byelaws for Environmental Protection by Dr. Pawan Kumar



Day 5 - Session 2: Urban Design Development Laws and Guidelines in India by Dr. Monalisa Bhardwaj



12. Weblink:

https://jaipur.manipal.edu/content/dam/manipal/muj/fod/Document/eventlist/13022023_PER_COA%20TRC%20FDP%202023_NS.pdf

13. Event Coordinators:

Chief Coordinator:

- **Dr. Madhura Yadav** (Professor, Architecture and Dean, FoD)

Online Coordinators:

- **Ar. Neha Saxena** (Asso. Prof., SA&D)
- **Ar. Ayushi Sharma** (Assist. Prof., SA&D)

Ar. Neha Saxena (Associate Professor, SA&D)

Dr. Sunanda Kapoor
Head, School of Architecture and Design

DEPARTMENT OF COMPUTER APPLICATIONS

in collaboration with

DIRECTORATE OF STUDENTS' WELFARE
&
CYPHER CLUB

Visit to Bhamasha Data Center

Outreach Activity

Date of Event: 15th September 2023

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1. **Introduction of the Event:** This was a visit to BHAMASHAH STATE DATA CENTER organized by the Cypher Club with Department of Computer Application, to increase the knowledge of students.

2. **Objectives of the Event:** This event aimed to enhance knowledge and give exposure to the students of data center that how they store the data, process the data and disseminating data and applications. This would give students a physical knowledge of IT operations.

3. **Beneficiaries of the Event:**

- Computer Applications student and faculty members

4. **Brief Description of the Event:**

With the help of this event students will better understand to work of the company and get familiar with environment of the IT sector. The event took place on 15th September 2023.Event will take place at BHAMASHAH Data Center.

5. **Poster:**

6. Photographs:

Fig 1 Group Pic

7. Schedule of the Event: 15th September 2023

8. Attendance of the Event:
Total Attendee- 240

S. No.	Enrollment No	Student Name
1	211015022	ARYAN PRANAMI
2	211015003	GATIM SAINI
3	221015035	Krishna Biyani
4	221020012	VATSAL GARG
5	221015148	KASHISH GIRDHANI
6	211015056	AMIT KUMAR PATEL
7	221015124	JAYANT SINGH RATHORE
8	211015032	VARUN JINDAL
9	211015082	VIBHOR TIWARI
10	221015149	PUSHPENDRA SINGH RATHORE
11	211015005	VISHAL RATHORE
12	211015010	ROHIT AJARIWAL
13	221015126	VANSH SHARMA
14	221020044	HARSHA JAIN
15	221015139	RITIK RAJ SHARMA
16	221020068	SUPRIO DAS

17	211015058	RAGHAV PUROHIT
18	221020014	DEEPANSH SHARMA
19	211015039	PARIKSHIT KAUSHIK
20	221015099	KSHITIJ KUMAR
21	221020035	AMAN KOTIYAL
22	221020033	KIRTI MAGHALANI
23	221015090	AVIRAL SINGH
24	221020069	SHUBHAM TOMAR
25	221020085	HARSHVARDHAN SINGH RAJAWAT
26	221015168	Charvi Solanki
27	221015143	VEER CHAUHAN
28	221020034	AAYUSHI ROCHLANI
29	221020063	JYOTI KUMARI
30	211015019	DEEKSH SINGH
31	211015072	ANNU BUNKAR
32	211015086	ISHA CHAUHAN
33	221015125	AMAN SHARMA
34	210901065	AMIT PAREEK
35	221020004	HARSH SHARMA
36	221015117	RAUNAK GULATI
37	211015051	RUDRANSH BHARDWAJ
38	211015036	SANCHIT SARDANA
39	221015152	HARSH RAJ NIMODIA
40	211015083	VIDHI GUPTA
41	221020085	HARSHVARDHAN SINGH RAJAWAT
42	211015023	YOGESHCHANDRA PANT
43	211015093	Preeti Guwalani
44	211015091	TANISHKA GUPTA
45	211015014	PULKIT SHARMA
46	211015080	AMAN YADAV
47	221020043	SIDDHARTH SHARMA
48	221015140	NIKHIL PRAJAPATI
49	221020050	ABHAY SHANKAR
51	221015104	Simran
52	211015084	ANUJ GUPTA
53	221020048	DEEPAK SHARMA
54	221015083	Rakesh S
55	221020041	RAHUL SAINI
56	221015096	MANVENDRA SINGH
57	221015116	PRIYANJALI BOTHRA
58	221020002	PRIYANKA SINGH
59	221020072	RAUNAK BOHRA
60	221015132	AYUSH BATRA
61	211015071	JAY SHARMA
62	211015090	ROSHAN BADAYA
63	221020070	JATIN KUMAR
64	211015066	GAUTAM SAMBLANI
65	211015067	RAGHAV REWARIA
66	221015012	Karni Singh

67	221020007	RITIK MITTAL
68	221020047	SOURABH PARWAL
69	221015089	BHARATKUMAR SOMARAM CHAUDHARY
70	221020057	CHOUDHARY NARESH
71	221015127	ANANYA PUROHIT
72	221020078	BHAVESH DEVJIBHAI VARMA
73	221020024	SHYAM GUPTA
74	211015010	ROHIT AJARIWAL
75	221015154	ARTHAV BHDAYA
76	221020065	SAGAR JAIN
77	221020053	PIYUSH DIXIT
78	221020087	PARVEN KHATWA
79	221020083	GAUTAMI SINGH JADOUN
80	221020032	AYUSH VIJAY
81	221020021	ARIJEET DEY
82	221015122	Yash
83	221020006	ANUBRATA MALLIK
84	211015015	MOHIT SINGH JAKHAR
85	221020036	DEEPAK CHOUDHARY
86	211015073	VIRAJ SHARMA
87	221015136	SAMUNDRA SINGH BHATI
88	211015017	ROOPAK MALLIK
89	211015029	SYED MOHAMMAD MEEZAAN CHISHTY
90	221015118	SREEYA ARLAGADDA
91	211015030	AKSHAT SONI
92	221020009	MOJ LADANI
93	221015130	SIDDHARTH KHIRWAL
94	221015141	ANISHA BADIWAL
95	211015033	TANISHKA SANJAY KAPIL
96	221020060	BHARTENDU KUMAR
97	221020027	HIMANSHU JANGID
98	211015007	PRANSHUL VIJAYVERGIA
99	211015079	ARSSH PRATAP SINGH
100	221020017	PRITAM SWAMI
101	221015121	MOHIT SINGH NARUKA
102	221015103	ABHISHEK PILLAI
103	211015077	MUSKAN GOYAL
104	221020074	CHENA RAM BIJARNIYA
105	221015097	BIPUL SARKAR
106	221015147	MAYANK PURI GOSWAMI
107	221020031	TANIYA SONI
108	221020084	OMPRAKASH JANGIR
109	221020075	AYUSH RAWAT
110	211015040	RISH0H JAIN
111	221020011	RAHUL SAINI
112	211015024	OM SHREYA
113	221020001	DINESH KUMAR ROCHANI
114	211015009	JATIN SADHNANI

115	211015004	ADITI BENDRE
116	221020080	SHASHANK JANGIR
117	221020081	RAMESH KUMAR
118	221020029	VINITA MATHUR
119	211015042	KULWANT SINGH RATHORE
120	211015014	PULKIT SHARMA
121	221020025	TEJARAM GURJAR
122	221015146	PRIYA JAIN
123	221020056	YASH KHARE
124	221020058	RITIK PATWA
125	221020010	SOUGATO ROY
126	211015038	KHEMENDRA SINGH KHANGAROT
127	211015087	PRATYAKSH BHANDARI
128	211015005	VISHAL RATHORE
129	221020073	SHREYANSH PANWAR
130	221015123	RUHUL RASHID ANSARI
131	221020086	RAGHAV BHAYANA
132	221020077	AYUSH SHARMA
133	221020061	SHUBH SRIVASTAVA
134	221015067	Avinash Saini
135	211015002	SUNIL KUMAWAT
136	211015011	JATIN PATTNAIK
137	211015016	KAVISH VINEET DESAI
138	211015021	RAKSHA AGARWAL
139	221015150	DIVYANSHI KEDIA
140	221020083	GAUTAMI SINGH JADOUN
141	221015144	RISHI KHURANIYA
142	221015092	MANAN KUMAWAT
143	221020074	CHENA RAM BIJARNIYA
144	221020049	ROHIT SOLANKI
145	221020046	ANTIMA PAREEK
146	211015069	VIDHI KHANDELWAL
147	221020030	APEKSHA KUMAWAT
148	211015084	ANUJ GUPTA
149	211015050	MANI RATNAM
150	211015057	RAHUL CHOUDHARY
151	211015064	VAIBHAV SAINI
152	211015078	SURYAANSH CHANDRA JAIN
153	221020051	SHIVAM TIWARI
154	221020059	INDERJEET YADAV
155	211015041	HARSH SARASWAT
156	221015146	Priya Jain
157	211015076	SATYAM CHOURASIA
158	221020052	SEJAL JAIN
159	221020003	AKANKSH PADGETWAR
160	221015133	NIKHIL SINGH CHAUHAN
161	221020042	ASEEM MALPANI
162	211015035	SHIVAM TAMBOLI

163	221015063	Harsh Vardhan Gurjar
164	221015153	KEWAL KRISHAN
165	211015085	RITAM MAITY
166	211015065	HARSH SHARMA
167	221020088	YASH SHARMA
168	211015062	PRAVEEN RATHORE
169	211015061	ANANYA GOYAL
170	211015046	ADITYA GUPTA
171	211015006	VATSAL BHUVA
172	211015027	BHUVAN MAHESHWARI
173	221020012	VATSAL GARG
174	221020045	VIJIT KUMAWAT
175	221015114	DIYA MURANI
176	211015037	SAMARTH KUSHWAHA
177	221020055	SHUBHAM KUMAR CHOUDHARY
178	221015142	SABOOR HAMDAAN
179	221015036	Dinesh Surthar
180	221020076	JAI SHARMA
181	211015044	DIYA SHARMA
182	221015088	GAUTAM CHOUDHARY
183	221015147	Mayank Puri
184	211015092	MANYA SHARMA
185	221020038	SAGAR KUMAR
186	221020071	MAHIPAL SINGH
187	221020010	SOUGATO ROY
188	211015049	SNEHA
189	221020023	AMAN SHARMA
190	221015129	DIPESH KUSHWAH
191	221015137	RITIKA SHARMA
192	221020066	ROHIT SWARNKAR
193	221015128	VIVEK SABNANI
194	221015115	ANIRUDDH SINGH
195	221015131	KRISHNA GEHANI
196	211015068	ACHINT GUPTA
197	211015015	MOHIT SINGH JAKHAR
198	211015053	LAKSHIT SHARMA
199	221020067	KUNAL SAHA
200	221020005	SAURABH AJAY BANSAL
201	221020020	HEMANG KUMAWAT
202	211015048	UTKARSH VIJAY TRIPATHI
203	211015043	HRICKBEDI DAS
204	211015089	SWAYAM JAIN
205	211015060	PRIYANSH KHANDELWAL
206	221020079	RITI SHARMA
207	221020026	DEEPAK KUMAR DHAKA
208	221015094	ADITYA BHATT
209	221020022	RITESH ANAND
210	211015017	ROOPAK MALLIK

211	211015054	REHANSH OJHA
212	211015013	ASHWANI CHHIPA
213	221020019	ADITYA SINGH
214	221015122	YASH BHATI
215	221015095	HARSHVARDHAN SINGH SHEKHAWAT
216	211015063	VARUN SHARMA
217	211015031	NAMISH TULI
218	221020082	AYUSH SHARMA
219	211020004	KUMARI AGRATA
220	211015088	PRIYANSHU KHALIYA
221	221020040	HARSH JANGID
222	221015093	MANVENDRA SINGH RATHORE
223	221015106	PRINCE KUMAR SAMARIYA
224	221015091	MANVENDRA SINGH RATHORE
225	221015145	PRINCE YADAV
226	221015144	Rishi Khervania
227	221020037	MANU SHARMA
228	221015120	RYAN CHHABRA
229	221020016	ABDULLAH RAHMAN
230	221015087	PRANVEER SINGH GAUR
231	211015081	ASHWINDER SINGH ARORA
232	211015008	HITEN JAIN
233	211015070	YUVRAJ PURI
234	211015012	GOVIND SUROLIYA
235	221020039	PRIYAM
236	221020064	KETAN KARTIK
237	221015091	Manvender Rathore
238	221015105	ANUSHKA SHARMA
239	221015155	BHUWAN GARG
240	211015085	RITAM MAITY

9. **Feedback of the Event**: Student felt immense pleasure by attending the session at data center and experiencing the technology presented over data center

Dr. Devershi Pallavi Bhatt (HOD)

MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

FACULTY OF DESIGN

International Conference on Sustainable Development for Heritage and Built Environment

22/06/2023 – 23/06/2023

Head, Department of Interior Design
SD&A, Faculty of Design
Manipal University Jaipur

Content of Report

1. Introduction of the Event
2. Objective of the Event
3. Beneficiaries of the Event
4. Brief Description of the event
5. Photographs
6. Poster of an Event
7. Schedule of the Event
8. Attendance of the Event

1. Introduction of the Event

The conference is inspired from the critical challenge of human, environmental, heritage and built sustainability concerning the present and future generations in a global-scale context. This theme emphasizes the strong foundation that is provided by using research to inform our everyday practices, policies, and analytical approaches. This interdisciplinary forum is for scholars, teachers, and practitioners from the built environment professional discipline who share an interest in—and concern for— sustainability in an holistic perspective, where environmental, cultural, economic and social concerns intersect. It will provide a platform for various individuals to connect the past and present and develop solutions to a more universal and environmentally friendly approach towards built environment.

The conference will include topics such as

(i)Sustainable approach to design in built environment,

(ii)Sustainability & built Heritage,

(iii)Conserving Built Heritage,

(iv)Sustainable Policies for Environmental and Infrastructure Planning,

(v)Earth and Environmental Planning & Design

2. Objective of the Event

This conference was a gathering of minds dedicated to addressing the pressing challenges of sustainability that affect our world today and tomorrow. It recognized that sustainability is a multifaceted concept that requires interdisciplinary collaboration and rigorous research. By bringing together scholars, educators, and practitioners, the conference facilitated the exchange of ideas and the development of solutions that promote a more sustainable, resilient, and environmentally friendly built environment.

3. Beneficiary of the event

This interdisciplinary forum is for scholars, teachers, and practitioners from the built environment professional discipline who share an interest in—and concern for— sustainability in an holistic perspective, where environmental, cultural, economic and social concerns intersect.

4. Brief Description of the event

The conference was hosted by Department of Interior Design and School of Architecture and Design, Faculty of Design at Manipal University Jaipur. This interactive and engaging event is tailored exclusively for our researchers, as part of our commitment to foster continuous learning,future research opportunities. The presentations focused on sustainability as the prime agenda and paved way for the researchers to present their work at an international level.

5. Photographs of the Event

Snippets of the Conference

6. Poster of the event

7. Schedule of the event

Time	Event	Speaker
11:00 – 11:30 AM	Opening speech	Dr Richa Jagatramka
11: 30 – 11:35 AM	Welcome address	Dr Madhura Yadav
11: 35 – 11:45 AM	Introduction of international speaker	Ar Himangshu Kedia
11: 45 AM – 12:45 PM	Presentation by Dr Muge	Dr Muge
12: 45 – 01:00 PM	Q & A session	
01:00 – 01:05PM	Vote of Thanks	Ar. Himangshu Kedia

Meeting Link :

https://teams.microsoft.com/l/meetup-join/19%3ameeting_MmRjNjZiN2ItMTc1NS00YmJlLTkwMTItMzBiYTVjNTI0YTRh%40thread.v2/0?context=%7b%22Tid%22%3a%227d0726e8-bf4b-4ac1-99f1-010fb11f1d3f%22%2c%22Oid%22%3a%2216be8839-914f-456c-9836-e6b3ba8fa2f9%22%7d

8. **Attendance of the Event**
   Total attendees – 28 participants from MUJ and outside

Sl.no	Name	Organisation
1	Dr. Richa Jagatramka	FOD
2	Megha Prabhu K	FOD
3	Dr. Sampath Kumar Padmanabha Jinka	FOD
4	Dr. Madhura Yadav	FOD
5	Dr. Anantkumar Dada Ozarkar	FOD
6	Dr. Subhash Chandra Devrath	FOD
7	Nisha Nelson	FOD
8	Preethi Agrawal	Practicing Architect and PhD scholar
9	NITIKA TORVI	Christ University
10	Subhadha B	Christ University
11	Himangshu Kedia	FOD
12	Rushikesh Kolte	MNIT
13	Dr. Sunanda Kapoor	FOD
14	Ananya Tripathi	AKTU - GCA
15	Kinzalk Chauhan	FOD
16	Ritu Sharma	FOS – Phd Scholar
17	Rimjhim Swami	FOD
18	Ayushi Sharma	FOD
19	Apoorva Agarwal	FOD
20	Muge Fialho Leandro Alves Teixeira	QUT Australia
21	Deeksha	MNIT
22	Siddharth Mishra	FOD
23	Akshay Gupta	FOD
24	Ritu Sharma	FOD
25	Neha Saxena	FOD
26	Antima Kuda	MAHE Dubai
27	Raunak Prasad	FOD
28	Ashutosh Saini	FOD

Head, Department of Interior Design
SD&A, Faculty of Design
Manipal University Jaipur

MANIPAL UNIVERSITY
JAIPUR

MUJ/DSW/Society Connect/ Oct2023/03

MANIPAL UNIVERSITY
JAIPUR

DIRECTORATE OF STUDENT'S WELFARE

(SOCIETY CONNECT)

#DAANUTSAV 2023

Plantation Drive

3rd October 2023

Date: 3rd October 2023

MANIPAL UNIVERSITY
JAIPUR

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6.	Brochure or creative of the event	5-6
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9.	Feedback of the Event	9
10.	Link of MUJ website	9

1. Introduction of the Event

"A nation that destroys its soils destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people. " Trees are indispensable for life. Man can't live without trees. However, the present condition of forests in the world, especially developing countries is pathetic and miserable. Forests are the source of life. They are the giving angels. They give man oxygen, rains, wood, fruit, make the world look so beautiful, yet the sinister man kills them! Who will be more inhumane than man himself? Cutting of forests ultimately endangers man's own existence. Trees are important to the environment; they recycle water and process carbon dioxide in the atmosphere through photosynthesis. They are the world's full-time purifiers of air and water. Their cutting will disturb the natural water cycles which will lead to the shortage of fresh water in the water reserves of the world.

Rotaract Green Club under Society Connect organized a Plantation Drive on account of DAAN UTSAV 2031. It took place on the 3rd of October from 10 a.m. Students were taken to the Mahatma Gandhi School, Begus for the drive. The drive aimed to instill a sense of discipline and respect for the environment while doing our part.

2. Objective of the Event

- Spread awareness on the importance of afforestation
- Direct students' mind in constructive activities
- Contribution to the society
- Promote tree planting
- Create awareness regarding importance of ecology
- Attempt at reducing pollution and improve green ambience

3. Beneficiaries of the Event

Community

4. Brief Description of the event

Rotaract Green Club organized the Plantation Drive on the 3rd October at 9 a.m. on account of DAAN UTSAV 2023. The drive's main aim was to direct student's mind

in constructive activities with the positive outcome through the facilitation of contributing to the nature and environment.

It also aimed at spreading awareness about the effects of global warming and the positive effects of planting trees. The students gathered on campus to go to the Mahatma Gandhi School, Begus.

The students participated in the drive enthusiastically and helped each other in planting the saplings. All the saplings were planted in the school ground by students. Participants were highly energetic to make the event a big success. A spirit of teamwork, exchange of ideas and enthusiasm of the participants especially among the students could be seen. Pictures were taken. The drive was successfully conducted by planting 40-50 saplings.

5. Photographs of the event

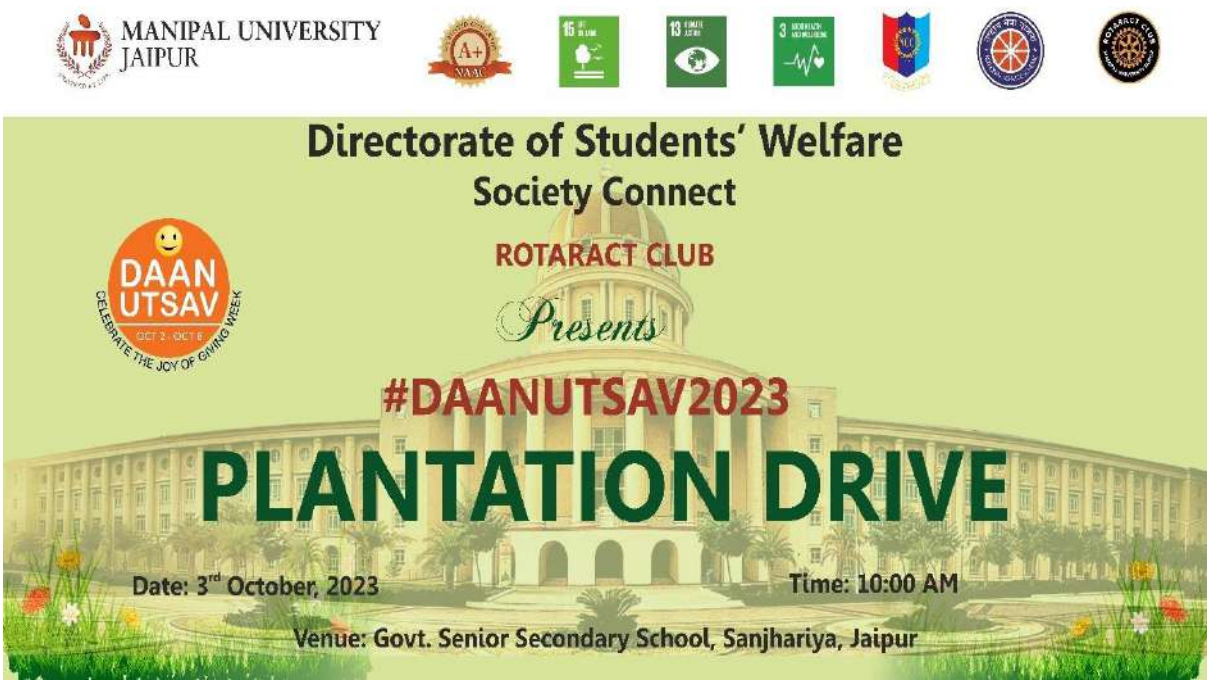
Image 1. Students and Faculty planting saplings

Image 2 Students participating in the Drive.

Students participating in the Drive.

Image 4 Giving the manure to the newly plant samplings

6. Brochure or creative of the event



Plantation Drive

7. Schedule of the event

S.NO.	Name of the Event	Time	Place
1.	Plantation Drive	10:00 AM	Mahatma Gandhi School (English Medium) Begus.

A bus from MUJ was taken to the school in the morning.

8. Attendance of the Event

Total attendee- 67

S.No.	Reg. NO.	Name of Students	Institute Name
1	23FE10ITE00079	Amisha anand	Manipal University Jaipur
2	23FE10CAI00360	shaivi adesh	Manipal University Jaipur
3	23FE10CSE00060	Amay Garg	Manipal University Jaipur
4	23FE10CDS00177	Manas Mathur	Manipal University Jaipur
5	23fe10bte00029	Saloni kamal	Manipal University Jaipur
6	23FE10CSE00508	Dev Dhawan	Manipal University Jaipur
7	23fe10cii00035	Bhargavi Anand	Manipal University Jaipur
8	220606004	Pranjal Puri	Manipal University Jaipur
9	23FA10BSP00028	Anupama Rustagi	Manipal University Jaipur
10	23FE10CCE00085	Siddhartha tiwari	Manipal University Jaipur
11	23FA10BAP00002	Tanisha Mathur	Manipal University Jaipur
12	23FD10BFD00009	Mariya Shabbir Baiwala	Manipal University Jaipur
13	23FE10CDS00224	Harsh Ajmera	Manipal University Jaipur
14	23fe10cds00125	Suryanshi Singh	Manipal University Jaipur
15	23fs10mat00009	Malavika ramdas	Manipal University Jaipur
16	221007021	Arshi Jain	Manipal University Jaipur
17	23FE10CSE00137	Stuti Dixit	Manipal University Jaipur
18	23fe10cii00094	Aarohi Tyagi	Manipal University Jaipur
19	23FE10CSE00152	Gautam Kakkar	Manipal University Jaipur
20	23FE10CSE00318	Krish Ray	Manipal University Jaipur
21	23FE10CII00076	Kriissh Marwaha	Manipal University Jaipur
22	229310321	Shiv Rajput	Manipal University Jaipur
23	23FS10BIO00051	Ragini Singh Thakur	Manipal University Jaipur
24	23FS10BIO00052	Anukriti sharma	Manipal University Jaipur
25	220901073	Diya Mittal	Manipal University Jaipur
26	23FE10CSE00081	Smmayan Gupta	Manipal University Jaipur
27	229309083	Raghav Gupta	Manipal University Jaipur
28	23FE10CDS00397	Hrishita Singh Timaney	Manipal University Jaipur
29	23FE10ITE00203	Sarah Sharda	Manipal University Jaipur
30	23fa10bsp00025	Jasleen kaur	Manipal University Jaipur

31	23FA10BSP00039	Jiya Kumar	Manipal University Jaipur
32	23FA10BSP00004	Aarya Mahale	Manipal University Jaipur
33	220606020	Chaarvi Kumar	Manipal University Jaipur
34	23fa10bsp00058	Kashvi Mahajan	Manipal University Jaipur
35	229301095	Shaurya Singh	Manipal University Jaipur
36	23fe10ece00024	Kushagra agrawal	Manipal University Jaipur
37	23FA10BSP00017	Megha Sharma	Manipal University Jaipur
38	23FM10BBA00162	Alina Nadeem	Manipal University Jaipur
39	23FM10BBA00178	Avishi Akhaury	Manipal University Jaipur
40	221007004	Urvi Thakare	Manipal University Jaipur
41	23FA10BAP00027	Natasha Joan Menezes	Manipal University Jaipur
42	23FA10BLE00004	Tanisha chaturvedi	Manipal University Jaipur
43	23fe10cai00579	Arjun Malhotra	Manipal University Jaipur
44	23FE10CAI00352	Maanyata Aul	Manipal University Jaipur
45	220901322	Divyanshi Singh	Manipal University Jaipur
46	229310412	Jatin Verma	Manipal University Jaipur
47	229301094	Yashovardhan Pratap Singh	Manipal University Jaipur
48	23FM10BBA00348	Niska kedia	Manipal University Jaipur
49	221105005	Dhruv Nair	Manipal University Jaipur
50	23FM10BBA00170	Shambhavi Agrawal	Manipal University Jaipur
51	23FE10CDS00241	Armaan Setia	Manipal University Jaipur
52	23FE10CAI00105	Mritunjay Singh	Manipal University Jaipur
53	229311075	Aarna Tyagi	Manipal University Jaipur
54	229302051	Prince jindal	Manipal University Jaipur
55	23FA10BHE00035	Taneesha puri	Manipal University Jaipur
56	220903033	Suhani Jain	Manipal University Jaipur
57	220901391	Dipika Agarwal	Manipal University Jaipur
58	229310222	Aayush Sharma	Manipal University Jaipur
59	221003007	Yachna Jain	Manipal University Jaipur
60	220901002	Anshu jangir	Manipal University Jaipur
61	23FE10CDS00284	Anant Barjatya	Manipal University Jaipur
62	221015074	Rupal Sharma	Manipal University Jaipur
63	23fa10bsp00047	Vartika Agarwal	Manipal University Jaipur
64	23FA10BSP00041	Kali Vithlani	Manipal University Jaipur
65	23FM10BBA00030	Harshal Saini	Manipal University Jaipur
66	23FE10CSE00746	Daksh Sharma	Manipal University Jaipur
67	23FS10BIO00034	PC Rahul	Manipal University Jaipur

9. Feedback of the Event:- The students participated enthusiastically.

(Hemant Kumar)

Assistant Director, Society Connect

Directorate of Student's Welfare

(Prof. AD Vyas)

Director, Directorate of Student's Welfare

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

MANIPAL UNIVERSITY
JAIPUR

Faculty of Management and Commerce

Department of Business Administration

Societal Connect Activity on

Bird Nest Installation

NOVEMBER 30, 2023

Head
Department of Business Administration
Manipal University Jaipur

1. **Introduction of the Event**

Introduction of the Event: School of Business and Commerce organized a activity to install bird nests in the nearby village on November 30, 2023. 5 students and 1 faculty member participated in the campaign. The event took place in nearby village of Manipal university.

2. **Objective of the Event**

The primary objective of the event was to promote environmental awareness and conservation by actively contributing to the well-being of local bird populations. Through the installation of bird nests, the aim was to create a sustainable habitat for birds in the nearby village, fostering biodiversity and ecological balance.

3. **Beneficiaries of the Event**

The beneficiaries of the event included the local bird species in the nearby village. By providing suitable nesting spaces, the initiative sought to enhance the living conditions for birds, contributing to the overall ecosystem health. Additionally, the participating students gained hands-on experience in environmental stewardship.

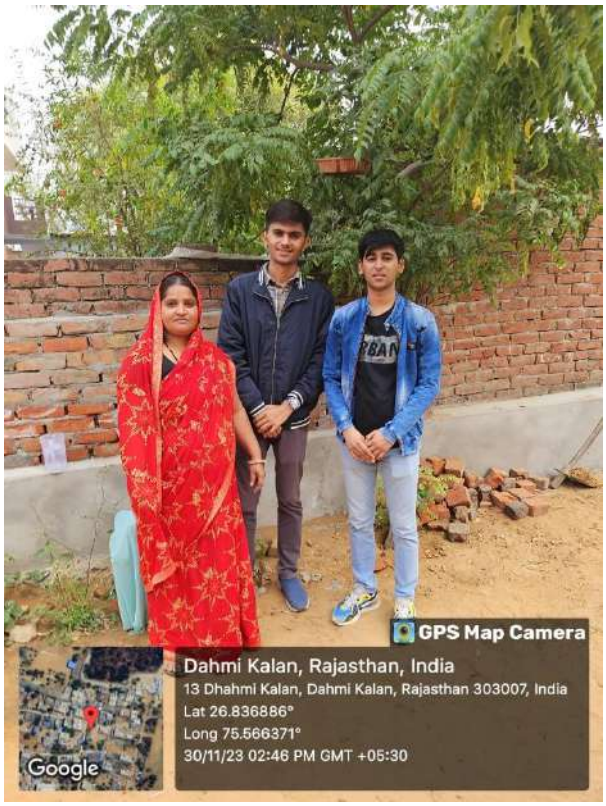
4. **Details of the Guests**

The event was laid by the students of BBA.

5. **Brief Description of the event**

The activity involved the installation of bird nests in the nearby village of Manipal University, with students and faculty members actively engaging in the process. Participants worked together to strategically place the nests, considering the local ecology and the needs of various bird species. The event not only contributed to the local environment but also provided a unique learning experience for the students, emphasizing the importance of hands-on conservation efforts. Overall, the initiative aimed to create a positive impact on the local ecosystem while instilling a sense of environmental responsibility among the participants.

6. **Photographs**



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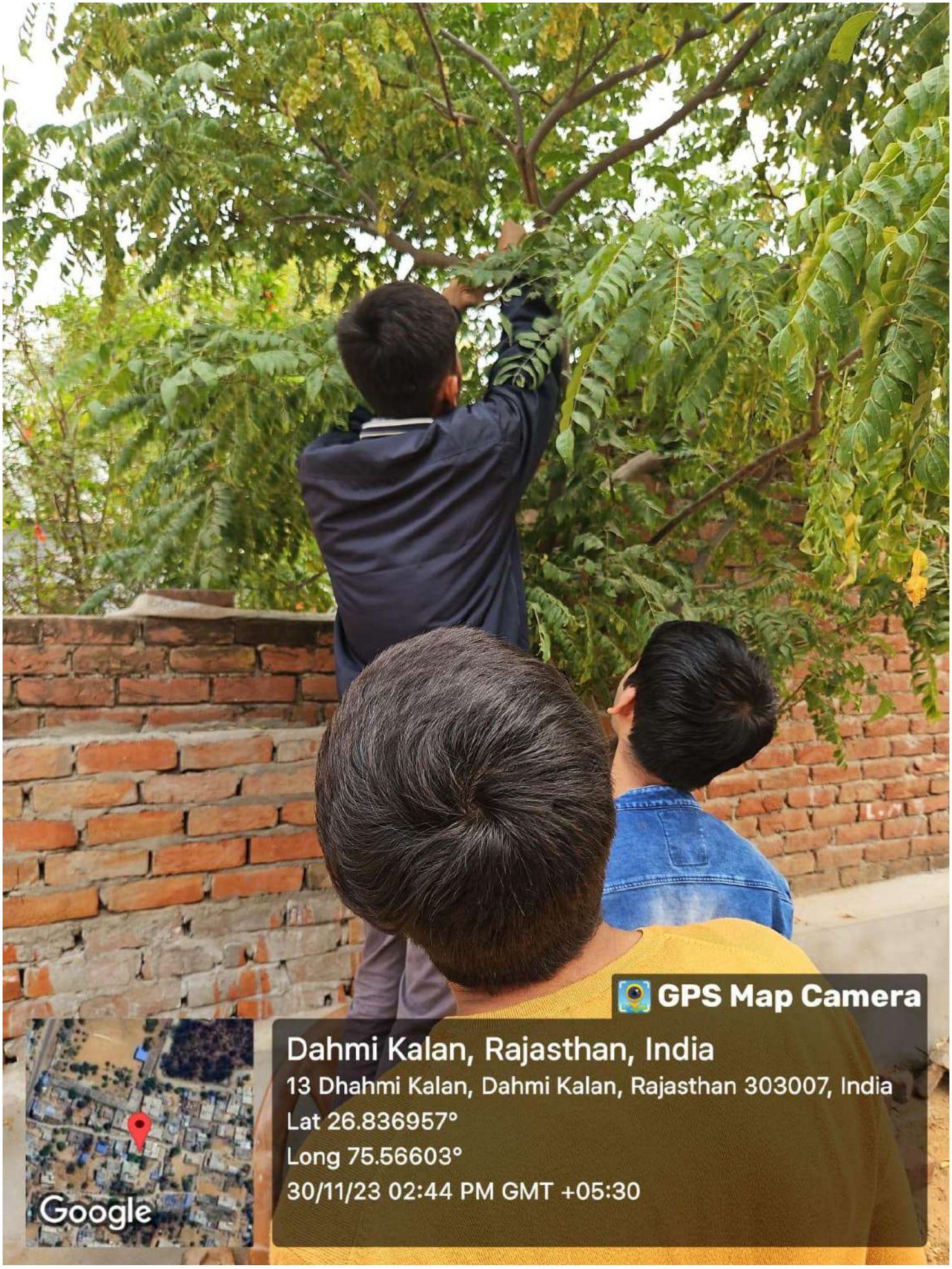
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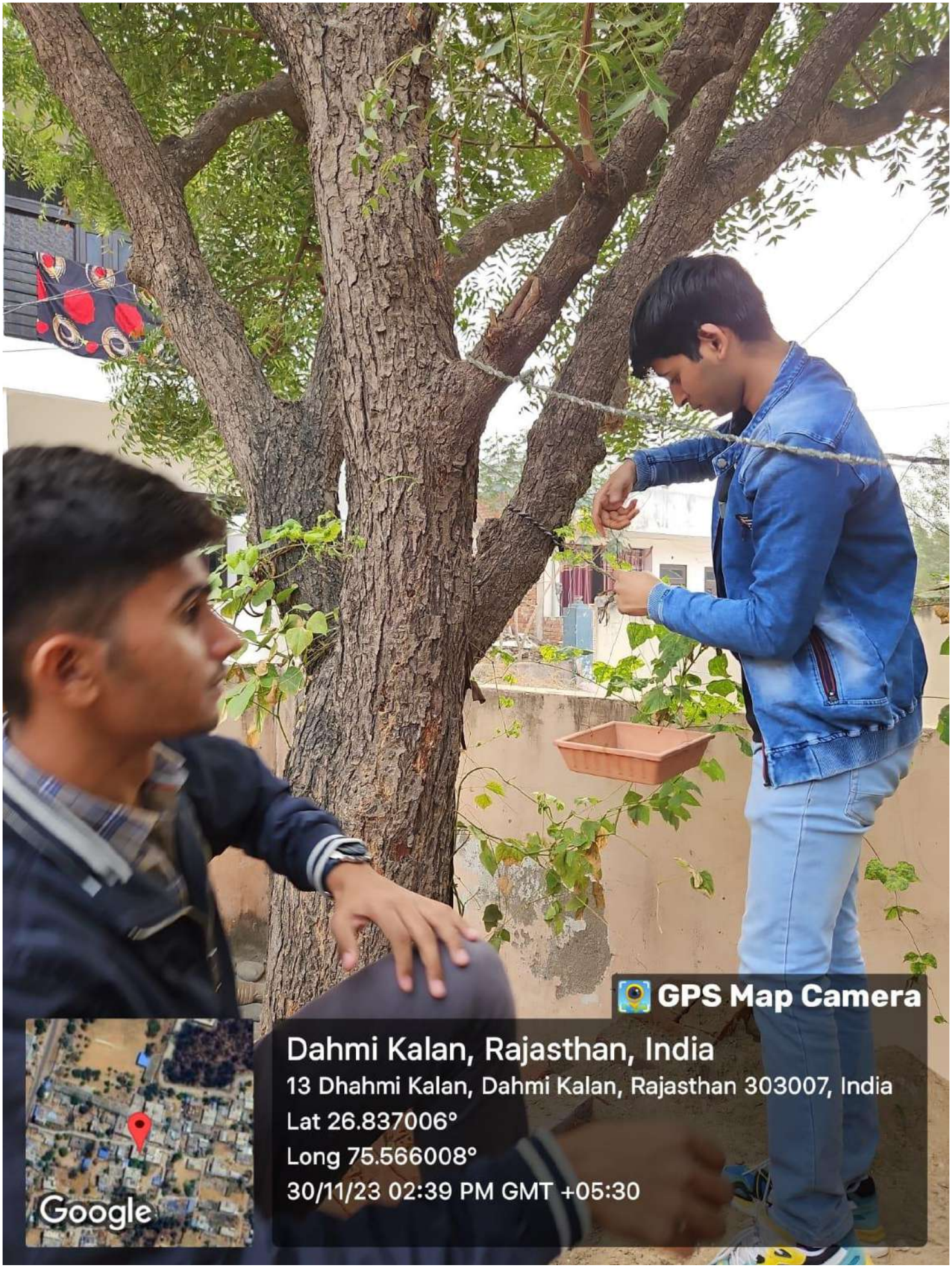
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Google

GPS Map Camera
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Unnamed Road, Dahmi Kalan, Rajasthan 303007, India
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Long 75.565537°
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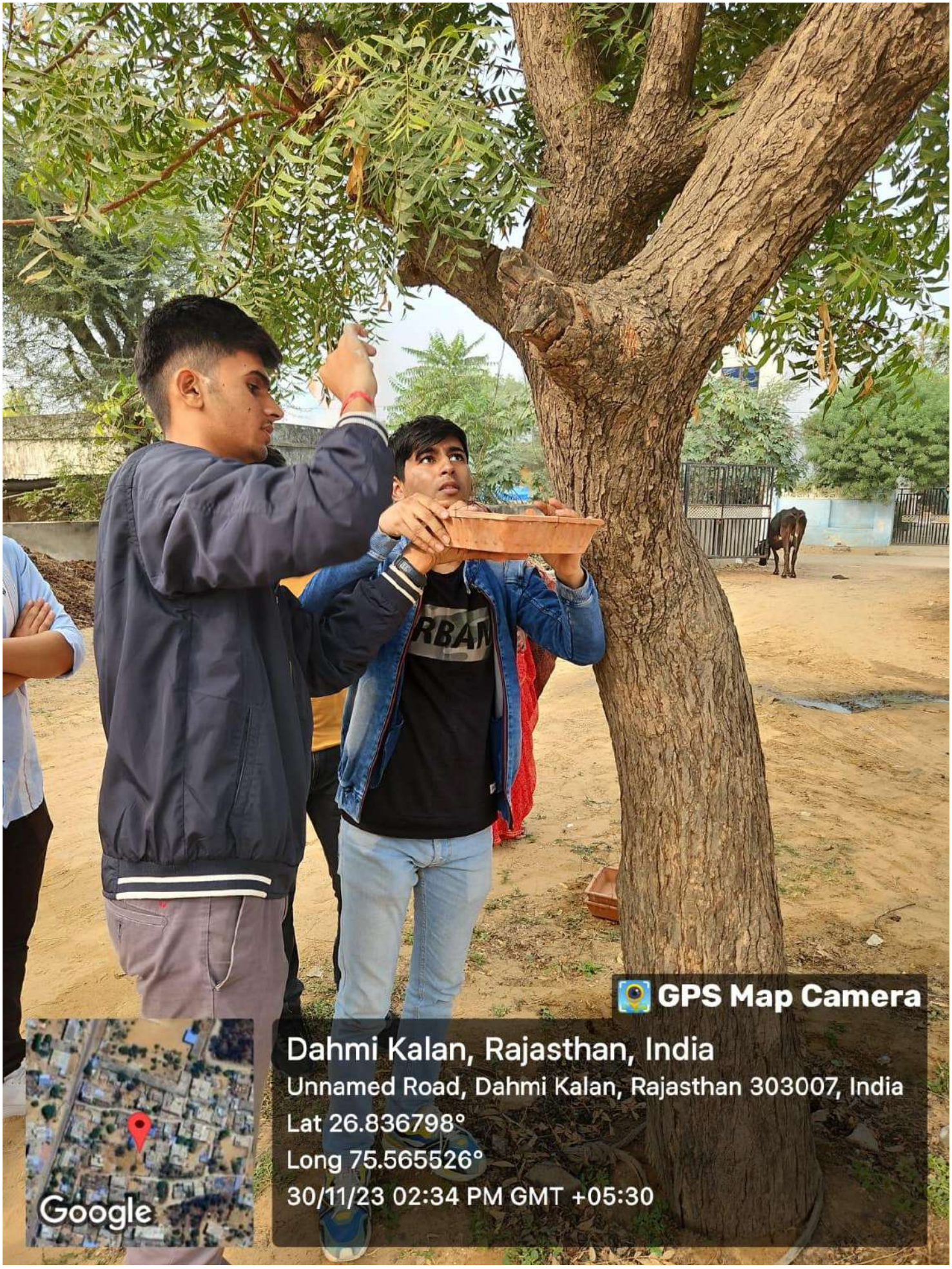
Google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Google

GPS Map Camera
Dahmi Kalan, Rajasthan, India
RHP8+X24, Dahmi Kalan, Rajasthan 303007, India
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Long 75.565522°
30/11/23 02:33 PM GMT +05:30
Google

GPS Map Camera
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RHP8+X24, Dahmi Kalan, Rajasthan 303007, India
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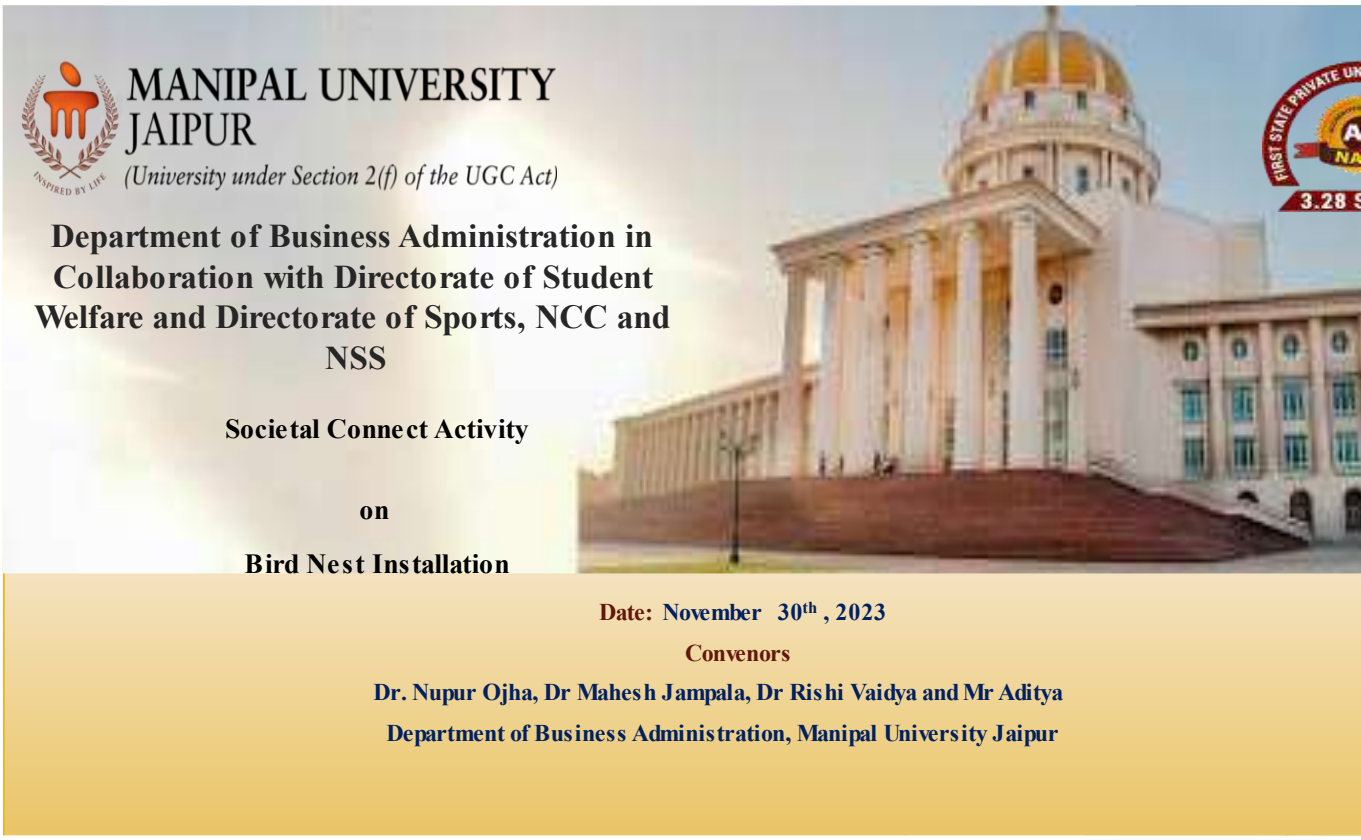
Google

7. Brochure or creative of the event



8. Schedule of the Event

The event took place on November 30, 2023

9. Attendance of the Event

Sr. No	Name of Institution	Registration Number/ Employee Code	Attendee Name
1	Manipal University Jaipur	MUJ0099	Dr. Mahesh Jampala
2	Manipal University Jaipur	MUJ1538	Dr Rishi Vaidya
3	Manipal University Jaipur	MUJ0623	Dr. Nupur Ojha
4	Manipal University Jaipur	MUJ1490	Mr. Aditya Dhiman
5	Manipal University Jaipur	23FM10BBA00204	DINESH CHOUDHARY
6	Manipal University Jaipur	23FM10BBA00200	VANSH MULCHANDANI
7	Manipal University Jaipur	23FM10BBA00214	GOPAL BISHNOI
8	Manipal University Jaipur	23FM10BBA00215	AKSHAT SHARMA
9	Manipal University Jaipur	23FM10BBA00216	KHUSHWANT SANKHLA
10	Manipal University Jaipur	23FM10BBA00205	AYUSHMAN GUPTA

Head
Department of Business Administration
Manipal University Jaipur

MANIPAL UNIVERSITY
JAIPUR

FACULTY OF ARTS

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF ECONOMICS

COMMUNITY OUTREACH VISIT

Date of Event- October 31, 2023

Content of Report (index)

1. Introduction of the Event
2. Objective of the Event
3. Beneficiaries of the Event
4. Details of the Guests
5. Brief Description of the event
6. Geo-tagged Photographs
7. Brochure or creative of the event
8. Schedule of the Event
9. Attendance of the Event
10. News Publication
11. Feedback of the Event
12. Link of MUJ website

1. Introduction of the Event

The practical knowledge about the subject is of immense importance for the students of B.A, Economics (Hons.), M.A. Economics (Hons.), and as such apart from regular classroom teaching there is a strong case for exposing them to innovative and practical outdoor sessions/visits to the nearby areas & projects. Taking this pedagogy of teaching, a one day visit to the renowned Laporiya village and interaction with **Padma Shree Laxman Singh** was planned to closely to observe how the water stressed Laporiya village became self-sufficient in water with all the efforts of **Laxman Singh** Ji. He has been awarded the Padma Shree for his significant contribution to the field of saving water and the environment for the last 40 years. He changed the picture of more than 50 villages with the technique of saving water and the campaign launched for it. He recharged the ponds with the Chowka technique to save water and pastures.

To take insights into his dedication, efforts, and commitments, this visit was planned for students to interact with him so that the **environmental sustainability** thought will sustain forever with **Gen-Z** and they will transfer the same to **Gen-Alpha.**

2. Objective of the Event

Water is a finite and shared resource. As well as being a basic human right and fundamental to healthy ecosystems, water is vital to the functioning of the global economy. However, increasing demand and competition, climate change and pollution are putting pressure on global water resources, creating risks for business and society. To experience the outstanding achievements and gain practical knowledge about environmental economics, an academic visit to "Laporiya village, near Dudu" is organized for the betterment and knowledge enhancement of the students.

3. Beneficiaries of the Event

Students and faculty members of Manipal University Jaipur.

4. Details of the Guests

The President of India has awarded Shri Laxman Singh Ji Padma Shree for his commendable work of reviving the Chowka system, a traditional water harvesting method in Rajasthan. He has founded the NGO Gram Vikas Navyuvak Mandal Laporiya (GVNML). The efforts of Sh. Laxman Singh Ji has borne fruits in a drought-ridden small village (Lapodiya), 80 km from Jaipur.

5. Brief Description of the event

It was an expert lecture on Syllogism of knowledge of economics, entrepreneurial and data skills: Unpack the Why? by Mr. Abhishek Jain, EY, Senior project consultant E & Y. The aim of the lecture is to provide economic knowledge, entrepreneurial skill with basic data analytics knowledge and skills when it comes to leveraging data while growing their businesses, regardless of their respective industries. Student's always be in prisoners dilemma of Why?

Photographs

3 to 5 geotagged photographs of the event or screenshots of the event (if online) with captions

Mr Laxaman Singh Ji discussing the importance of ecosystem

Mr Laxaman Singh Ji Addressing the students

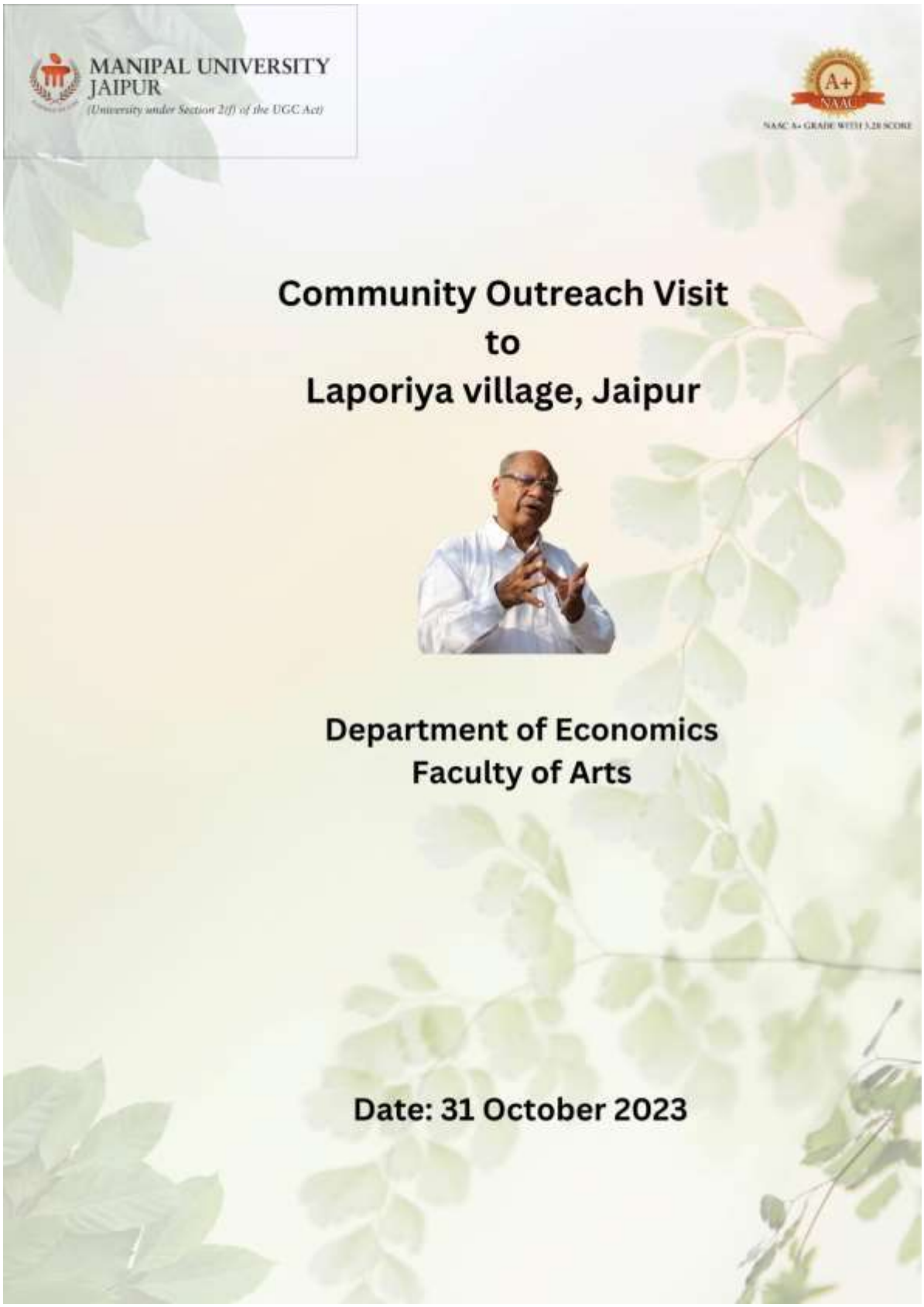
The Village well

Taking a short break, Mr Lakshman Singh Ji, faculties and students

Mr Singh (centre) discussing the young mind's learnings and impressions in his house at the end of the visit.

The students, Mr Lakshman Singh (towards right in white) and Dr Shilpi Gupta, outside his house.

6. Brochure or creative of the event (insert in the document only)



7. Schedule of the event (insert in the report)

Date of the event –October 31, 2023 7:30 AM

8. Attendance of the Event (insert in the document only)

Total attendee-

Registration No.	Name of the Students	Column1	Column2
211101046	Akshay	P	
211101035	Anubhav	p	
211101003	Dakshita	P	
211101043	Gaurav basniwal	P	
211101050	Gaurav kumar	P	
211101013	Saarthak tiwari	P	
211101042	Praseeda	P	
211101004	Rishita	P	
211101006	Shivangi	P	
211101015	Sumriddhi	P	
211101040	Yash	P	
211101041	Yashi	P	
211101039	Anushka	P	
211101007	Utkarsh	P	
211101044	Riti	P	
211101021	Paritosh	P	
211101028	Divya surana	P	
211101025	Atharv	P	
23FA20MEA00004	Santanu Bhowmick	P	
23FA20MEA00007	Anubhav Joshi	P	
23FA20MEA00005	Bhumita Yadav	P	
23FA20MEA00006	Shweta Choudhary	P	
23FA20MEA00003	Medini Choudhary	A	Unwell
23FA20MEA00002	Nisha Choudhary	A	Unwell
231151001	Devanshi Kapoor	P	
Dr. Shilpi Gupta	Associate professor - Department of Economics	P	
Mr. Apoorva Saxena	Head, community Radio Station	P	
Mr. Parul Kanwar	Jr. Assistant SHSS	P	

News Publication- News printed in newspaper or online links (if any) for news – insert images)
NA

9. Feedback report of the Event

Students experienced Padam Shree Laxman Singh Ji's dedication, efforts, and commitments, and take away from him the **environmental sustainability** thought which will sustain forever with **Gen-Z** and they will transfer the same to **Gen-Alpha.**

10. Link of MUJ website stating the event is uploaded on website

Dr. Monika Mathur
Head, Department of Economics
Manipal University Jaipur

Seal and Signature of Head with date

MANIPAL UNIVERSITY JAIPUR

FACULTY OF ARTS

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

DEPARTMENT OF ARTS

Tree plantation Drive

Social outreach event in collaboration with DSW and NCC

06/09/2023

Index

1. Introduction of the Event
2. Objective of the Event
3. Beneficiaries of the Event
4. Details of the Guests
5. Brief Description of the event
6. Geo-tagged Photographs
7. Brochure or creative of the event
8. Schedule of the Event
9. Attendance of the Event
10. News Publication
11. Feedback of the Event
12. Link of MUJ website

1. **Introduction of the Event**
   The Department of Arts in collaboration with the DSW (NCC and NSS) organized a tree plantation drive with a number of BA(Liberal Arts) students.

2. **Objective of the Event (bullet points or about 50 words)**

To make the students aware of the importance of tree plantation.

3. **Beneficiaries of the Event**

   Government school, Begas, an adopted school of MUJ

4. **Brief Description of the event**
   The Department of Arts in collaboration with the DSW (NCC and NSS) organized a tree plantation drive with a number of BA(Liberal Arts) students. The objective of the event was to make the students aware of the importance of tree plantation.

5. Photographs

Students engaged in a tree plantation drive in the government school, Begas

GPS Map Camera
Begas, Rajasthan, India
VHF2+FP2, Begas, Rajasthan 303007, India
Lat 26.873903°
Long 75.552877°
06/09/23 11:26 AM GMT +05:30
Google

MUJ students with the government school students

MUJ department students during the plantation drive

6. Brochure or creative of the event (insert in the document only)

8x4.5 feet

7. Schedule of the event (insert in the report)

6th September, 11:00 a.m. to 12:00 p.m.

8. Attendance of the Event (insert in the document only)
Total attendee-16

Sr. No	Name of Institution	Place of Institution	Name of Attendee	Name of Dept
1.	MUJ	Jaipur	Chandravardhan	Arts
2.	MUJ	Jaipur	Kumesh Mishra	Arts
3.	MUJ	Jaipur	Soumya Pareek Dhanushree	Arts
4.	MUJ	Jaipur		Arts
5.	MUJ	Jaipur	Karan Mallick	Arts
6.	MUJ	Jaipur	Vanshika Agarwal	Arts
7.	MUJ	Jaipur	Prithviraj	Arts
8.	MUJ	Jaipur	Akshatt Singh	Arts
9.	MUJ	Jaipur	Dhruv Nair	Arts
10.	MUJ	Jaipur	Krishna	Arts
11.	MUJ	Jaipur	Gaury	Arts
12.	MUJ	Jaipur	Sudeepti Dhruv Dahiya	Arts
13.	MUJ	Jaipur	Aditi Panigrahi	Arts
14.	MUJ	Jaipur	Aradhya Khandelwal	Arts
15.	MUJ	Jaipur	Komal Chadha	Arts
16.	MUJ	Jaipur	Krritika Khandelwal Pragya Sharma	Arts
17.	MUJ	Jaipur	Prachi Randhawa	Arts
18.	MUJ	Jaipur	Gurmehr Singh	Arts
19.	MUJ	Jaipur	Himmat di Charan	Arts
20.	MUJ	Jaipur	Sameer Khan	Arts
21.	MUJ	Jaipur	Ananya Thakur	Arts
22.	MUJ	Jaipur	Harshita Das	Arts
23.	MUJ	Jaipur	Manan Sharma	Arts

24.	MUJ	Jaipur	Surendra Singh	Arts
25.	MUJ	Jaipur	Joy Tak	Arts
26.	MUJ	Jaipur	Soumya harma	Arts
27.	MUJ	Jaipur	Deepak	Arts
28.	MUJ	Jaipur	Anup Choudhary	Arts
29.	MUJ	Jaipur	Prithviraj Hada	Arts
30.	MUJ	Jaipur	Tanisha Vashisht	Arts

9. Link of MUJ website stating the event is uploaded on website

https://jaipur.manipal.edu/muj/news-events/events-list.html

Dr. Mani Sachdev
Head, Department of Arts
Manipal University Jaipur

15.9.23

Seal and Signature of HOD

DIRECTOR STUDENT WELFARE & PROCTOR
MANIPAL UNIVERSITY, JAIPUR

(Prof. AD Vyas)
Director, Directorate of Student's Welfare

COLLABORATIONS

Rotary
Year 2022-2023

ROTARY CLUB JAIPUR BAPU NAGAR

Club ID 73485 R.I. District 3054 Charter Date 21-06-2006

IMAGINE ROTARY
(Rotary Theme 2022-23)

Rotary International President
Rtn **Jennifer Jones**

District Governor
Rtn Dr **Balwant Singh Chirana**

President
PHF Rtn **Radhey Shyam Gupta**
D-13, Indra Puri Colony, Lal Kothi,
Jaipur, Rajasthan 302015 (India)
Mobile: +91-9414779184
eMail: rsgupta9414@gmail.com

Secretary
PHF Rtn **Meeta Mathur**
G-2, Janpath, Shyam Nagar,
Jaipur Rajasthan 302019 (India)
Mobile: +91-9982659532
eMail: alokmeeta@yahoo.com

Treasurer
Rtn **Brajesh Kumar Gupta**
D-28, Indra Puri Colony, Lal Kothi,
Jaipur, Rajasthan 302015 (India)
Mobile: +91-9829072271
eMail: brajeshkgupta24@gmail.com

Club Patron
Maj Donor Rtn Dr **Sudhir Kumar Calla**

President Elect (2024-25)
PHF Rtn CFP **Shalini**

Immediate Past President
MPHF Rtn Er **Narendra Mal Mathur**

Vice Presidents
MPHF Rtn Adv **Ashok Goyal**
PHF Rtn **Desh Deepak Goyal**

Jt. Secretary
Rtn Er **Nand Kishore Maheshwari**

Director – Club Administration
PHF Rtn **Rajendra Tiwari**

Director – Service Projects
Rtn Er **Sudesh Roop Rai**

Director – Environment Service
Rtn **Shyam Sunder Gupta**

Director – Foundation
MPHF Rtn **Vipan Bahl**

Director – Literacy & T.E.A.C.H.
PHF Rtn Dr **Arun Kumar Arya**

Director – Membership
PHF Rtn **Jwala Prasad Sharma**

Director – Public Image & Fellowship
PHF Rtn **Chander Mohan Mahajan**

Director – Publications
PHF Rtn **Basant Jain**

Director – Youth Service
Rtn Prof **Anil Dutt Vyas**

Executive Secretary - I.T.
PHF Rtn Prof **Raj Kishor Pareek**

Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 31 Oct 23

TO WHOMSOEVER IS CONCERN

Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted a Awareness on Environmental Protection at Dehmi Kalan Village by planting the 15 plants in village on 31st Oct 2023. It was a physical activity involving the students from NSS, DSW and the Rotaract Club MUJ. Event was well coordinated by the Department of Business Administration

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

Rotary
Year 2022-2023

ROTARY CLUB JAIPUR BAPU NAGAR

Club ID 73485 R.I. District 3054 Charter Date 21-06-2006

IMAGINE ROTARY
(Rotary Theme 2022-23)

Rotary International President
Rtn **Jennifer Jones**

District Governor
Rtn Dr **Balwant Singh Chirana**

President
PHF Rtn **Radhey Shyam Gupta**
D-13, Indra Puri Colony, Lal Kothi,
Jaipur, Rajasthan 302015 (India)
Mobile: +91-9414779184
eMail: rsgupta9414@gmail.com

Secretary
PHF Rtn **Meeta Mathur**
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Jaipur Rajasthan 302019 (India)
Mobile: +91-9982659532
eMail: alokmeeta@yahoo.com

Treasurer
Rtn **Brajesh Kumar Gupta**
D-28, Indra Puri Colony, Lal Kothi,
Jaipur, Rajasthan 302015 (India)
Mobile: +91-9829072271
eMail: brajeshkgupta24@gmail.com

Club Patron
Maj Donor Rtn Dr **Sudhir Kumar Calla**

President Elect (2024-25)
PHF Rtn CFP **Shalini**

Immediate Past President
MPHF Rtn Er **Narendra Mal Mathur**

Vice Presidents
MPHF Rtn Adv **Ashok Goyal**
PHF Rtn **Desh Deepak Goyal**

Jt. Secretary
Rtn Er **Nand Kishore Maheshwari**

Director – Club Administration
PHF Rtn **Rajendra Tiwari**

Director – Service Projects
Rtn Er **Sudesh Roop Rai**

Director – Environment Service
Rtn **Shyam Sunder Gupta**

Director – Foundation
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PHF Rtn Dr **Arun Kumar Arya**

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Director – Public Image & Fellowship
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Director – Publications
PHF Rtn **Basant Jain**

Director – Youth Service
Rtn Prof **Anil Dutt Vyas**

Executive Secretary - I.T.
PHF Rtn Prof **Raj Kishor Pareek**

Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 03/10/23

TO WHOMSOEVER IS CONCERN

Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted a Plantation Drive at Mahatma Gandhi Government School (English Medium), Begas on 3rd October 2023. It was a physical activity involving the students from NSS, DSW and the Rotaract Club MUJ.

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

Rotary
Year 2022-2023

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Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 26 Oct 23

TO WHOMSOEVER IS CONCERN

Dept of Chemistry and Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted Plantation Drive at Dadar ki Dhani Village. Event was well coordinated by the Department of Chemistry and DSW.

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

Rotary
Year 2022-2023

ROTARY CLUB JAIPUR BAPU NAGAR

Club ID 73485 R.I. District 3054 Charter Date 21-06-2006

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Director – Youth Service
Rtn Prof **Anil Dutt Vyas**

Executive Secretary - I.T.
PHF Rtn Prof **Raj Kishor Pareek**

Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 06/09/23

TO WHOMSOEVER IS CONCERN

Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted a Plantation Drive at Mahatma Gandhi Government School (English Medium), Begas on 6th September 2023. It was a physical activity involving the students from NSS, DSW and the Rotaract Club MUJ. Event was well coordinated, where more then 30 samplings of plants were planted in the schools.

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

Rotary
Year 2022-2023

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President
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Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 25 Oct 23

TO WHOMSOEVER IS CONCERN

Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted campaign on Swach Bharat Abhiyan on October 25 2023 at Dehmi Kalan. An awareness session is taken by Team MUJ physically involving the students from NSS, DSW and the Rotaract Club MUJ. Event was well coordinated by the Department of Business Administration.

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

Rotary
Year 2022-2023

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Club Trainer
MPHF Rtn **Ravi Shanker Sharma**

Sergeant at Arms
PHF Rtn Er **Satish Goyal**

Date: 24/08/23

TO WHOMSOEVER IS CONCERN

Rotaract Club, Directorate of Students' Welfare along with Rotary Club Jaipur, Bapu Nagar conducted a Plantation Drive at Mahatma Gandhi Government School (English Medium), Dehmi Kalan on 24th August 2023. It was a physical activity involving the students from NSS, DSW and the Rotaract Club MUJ.

We would like to appreciate Rotaract Club, Directorate of Students' Welfare, Manipal University Jaipur for the efforts and express our gratitude towards them.

Regards

Rtn Meeta Mathur
Secretary

MANIPAL UNIVERSITY
JAIPUR
(University under Section 2(f) of the UGC Act)

Name of Partnering Organizations:
Department of Electrical Engineering, Malaviya National Institute of Technology, Jaipur, India

Name of Participants:
P. Agrawal, N. Gupta, K. R. Niazi, A. Swarnkar

Name of the Activity:

Research Work on 'Distribution System Operation with Minimum Topological Variations'
(Book Chapter)

Distribution System Operation with Minimum Topological Variations

Praveen Agrawal, Neeraj Kanwar, Nikhil Gupta, K. R. Niazi, and Anil Swarnkar

Abstract Distribution network reconfiguration (DNR) is a well-established operational strategy for distribution systems to improve its performance. Also, several social and techno-economic objectives can also be effectively achieved in contemporary distribution systems by optimally placing distributed resources (DRs). However, with integration of DR, distribution system becomes active distribution systems and it has dynamically changing nature of load and generation. Therefore, it is important to reinvestigate the effectiveness of existing NR strategy. In this paper, a new NR strategy is suggested for power loss minimization where the network topology varied only once during a day. An investigation is carried about existing and proposed reconfiguration strategies while considering some realistic scenarios pertaining to contemporary distribution systems. The application results are shown on 33-bus test distribution system.

Keywords Distributed resources · Network reconfiguration · Smart grid

1 Introduction

In the present scenario, the distribution systems are taking new shapes by utilization of diverse distributed resources (DRs), automation in switching and other related control schemes, etc. On the other hand, the system performance is the biggest challenge in present competitive and deregulated environment. However, topological structure regulation of distribution networks can provide better electric power and more benefit to electric power companies [1]. This process is known as network reconfiguration (NR). However, the benefits of NR may be substantially reduced in the presence of optimally placed DRs as they can also effectively manage power

P. Agrawal · N. Gupta · K. R. Niazi · A. Swarnkar
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S. K. Goyal et al. (eds.), *Flexible Electronics for Electric Vehicles*, Lecture Notes in Electrical Engineering 1065, https://doi.org/10.1007/978-981-99-4795-9_16

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CERTIFICATE

This is to certify that ***Dr. Dinesh Sharma*** *Of .****Manipal Univ.*** *Jaipur has delivered a* ***Key Note Speech*** *on* **"Soil Parameter Monitoring Methodologies"** *in* **1th** ***International Conference On Recent Engineering Advancements & Computing Technologies (IC-REACT 2023),*** *Organized by VIST Bhopal MP India during 29th and 30th Sept. 2023.*

Dr. Rajeev Arya	**Dr. Ramanand Singh**	**Dr. Paresh Rawat**
Director VIST	**Secretory ARESS**	**President ARESS**

#UKLO Annual International Scientific Conference 2023

horizons International Scientific Journal University St. Kliment Ohridski in Bitola

SUSTAINABLE DEVELOPMENT GOALS

UKLO Annual International Scientific Conference 2023

On the occasion of the *World Science Day for Peace and Development*, the University "St. Kliment Ohridski" - Bitola is announcing a Call for Papers for its *Annual International Scientific Conference 2023* on the following topic:

"MULTIDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT GOALS"

Bitola, Republic of North Macedonia 17 - 18 November 2023

Mode: Hybrid

World Science Day for Peace and Development emphasizes the importance of science in society and the necessity to involve the broader public in discussions about emerging scientific topics. It highlights the value and applicability of science to our everyday lives.

The 2023 Conference topic is: "Multidisciplinary Approach to Sustainable Development Goals". Authors are invited to submit papers on any subject related to and within the scope of the Conference topic. Submissions from academics, researchers, and practitioners at any stage of their career, including PhD students, will be accepted.

Short overview:

World Science Day for Peace and Development, celebrated annually on 10 November, emphasizes the importance of science in society and the necessity to involve the broader public in discussions about emerging scientific topics. It highlights the value and applicability of science to our everyday lives. This international scientific conference offers the chance to mobilize the academy and experts from home and abroad around the issue of science for peace and development with a single purpose - *changing the world for the better!* The Conference will open for discussion on the most pressing issues of the UN Agenda 2030: 1. Eliminate Poverty; 2. Erase Hunger; 3. Establish Good Health and Well-Being; 4. Provide Quality Education; 5. Enforce Gender Equality; 6. Improve Clean Water and Sanitation; 7. Grow Affordable and Clean Energy; 8. Create Decent Work and Economic Growth; 9. Increase Industry, Innovation, and Infrastructure; 10. Reduce Inequality; 11. Mobilize Sustainable Cities and Communities; 12. Influence Responsible Consumption and Production; 13. Organize Climate Action; 14. Develop Life Below Water; 15. Life on Land; 16. Guarantee Peace, Justice, and Strong Institutions; 17. Build Partnerships for the Goals.

Important Dates:

- **20 September 2023:** Abstracts submission (up to 300 words in length)
- **17 and 18 November 2023:** Conference dates
- **05 December 2023:** Submission of final papers. Earlier submission of the papers helps us to manage the review process on time. Prepare your final paper following our Guidelines. Papers should be sent as .doc or .docx attachments via the e-mail address: conference@uklo.edu.mk

Submission details:
Interested authors are invited to submit an abstract (up to 300 words in length) and a brief academic CV written narratively by 20 September 2023 via the following link:
https://docs.google.com/forms/d/e/1FAIpQLSfxjz1J0DRQy7GYTCm11mdUffQWeDM_dn2gBh9SowUEKu3cSQ/viewform?vc=0&c=0&w=1&flr=0

Publication:
Submitted articles are subject to initial editorial screening and anonymous peer review by at least two reviewers. Selected papers will be published in a special issue of the *Horizons – International Scientific Journal* (https://uklo.edu.mk/ojs/index.php/horizons/index) as a peer-reviewed, interdisciplinary, and international journal published by the University St. Kliment Ohridski in Bitola, indexed in EBSCO, CrossRef, Google Scholar, etc.

Certification:
The papers accepted and presented during the Conference will receive a certification of participation.

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Assist. Prof. Dr. Blagoj Nenovski, University "St. Kliment Ohridski" - Bitola, North Macedonia

Short Article Guidelines

Article title: Times New Roman; 14 pt; bold; alignment centered; single-line spacing; All Caps (max. 100 characters with spaces).

Author details: Times New Roman; 12 pt; single-line spacing; alignment centered. Please write the author details in the following order:

John Galt
University "St. Kliment Ohridski" - Bitola, North Macedonia
ORCID iD: https://orcid.org/0000
E-mail: galt@uklo.edu.mk

Abstract and keywords: Between 150 and 200 words (5-7 keywords); Times New Roman; 12 pt; single-line spacing; justify. Write your abstract using concise, but complete, sentences. Get to the point quickly and always use the past tense because you are reporting on a study that has been completed. There are four things you need to include: 1) your research problem and objectives, 2) your methods, 3) your key results or arguments, and 4) your conclusion.

Article text: Times New Roman; 12 pt; justify; 1.0 line spacing; margins: Top: 2,5 cm; Bottom: 2,5 cm; Left: 3 cm; Right: 3 cm. The scope of submitted text should not exceed more than 30.000 characters (with spaces) including references. The text should be written in the neuter gender, concisely with correct orthography. Latin phrases should be set in *italics*.

Quotations: If they are brief (3 lines or fewer), quotations should be run on with the text. Longer quotations should be indented, without quotation marks. All indented quotations should be typed single-spaced.

Citation style: The author should follow Chicago Style (author-date system) for referencing, for example: (Dahl 1989, 45); (Geddes 1999, 134-43); (Linz 1975). All references should be given in full at first mention. Subsequent citations can be abbreviated. Footnotes should be kept to a minimum.

Headings and subheadings: Times New Roman; 12 pt; bold.

Tables: Times New Roman; bold; size 10; align heading left; single line spacing. Tables must be created in Word, not Excel. The table heading is situated above the table.

Figures: Times New Roman; bold; size 10; alignment centered; single line spacing. The authors must submit original electronic copies of the figures applied in the article in TIFF, JPG, or PNG format. Figure heading is situated under the figure. Consider aligning tables and figures at the center.

Dates: Dates should be given in the form: 26 December 1981.

Conclusion: The conclusion is intended to help the reader understand why your research should matter to them after they have finished reading the article. A conclusion is where you summarize the article's findings and generalize their importance, discuss ambiguous data, and recommend further research.

These include:

- Presenting the last word on the issues you raised in your article.
- Summarizing your thoughts and conveying the larger implications of your study.
- Demonstrating the importance of your ideas.
- Introducing possible new or expanded ways of thinking about the research problem.

References: The reference list appears at the end of your article, and provides more detailed information about the sources you cited. Each entry in the reference list also begins with the author's last name and the publication date, so that your reader can easily find any source they encounter in the text. For four or more authors, list all of the authors in the reference list; in the text, list only the first author, followed by *et al*. It is alphabetized by the author's last name.

References Examples:

Articles:
Author's surname, Name. year of publication. "Article Title". *Horizons* 8 (1):229-4, DOI: XXX-XXX
Books:
Author's surname, Name. year of publication. *Book Title*. place of publication: publisher.
Contributions in compilations and edited volumes:
Author's surname, Name. year of publication. "Title", In: editor's surname, forename initials (ed./eds.) Compilation (place of publication: publisher), pages interval, DOI: XXX-XXX
Internet (URL):
When articles, books, or official documents are accessed via the internet, the reference should be formatted as described above; Full URL. where the document is posted should be listed as well as the date when it was accessed.
Author's surname, Name. year of publication. *Book Title*. place of publication: publisher, available at: http://xxxxxxxxxxxxxxxx (26 December, 2021).
Legislation: Acts and Regulations
The titles of pieces of legislation (Acts, Regulations, rules, and by-laws) should be cited exactly - do not alter spelling or capitalization.
In-Text Citation:
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Title of the Act and Date of publication (abbreviation of the jurisdiction)

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***We suggest utilizing reference management software like Zotero, Mendeley, and similar tools.**

Organizer:
University "St. Kliment Ohridski" - Bitola, Republic of North Macedonia

For more information about the Conference, please contact us:
Contact phone: +389 47 223 788
E-mail: conference@uklo.edu.mk
Web page: www.uklo.edu.mk

We appreciate your interest in our Conference and looking forward to your submission soon. Please forward this information to your colleagues and students.

Kind Regards,
Conference Organizing Team

Fw: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>

Thu 13/07/2023 17:04

To:goran.ilik@uklo.edu.mk <Goran.ilik@uklo.edu.mk>;nurten.sulejmani@uklo.edu.mk <nurten.sulejmani@uklo.edu.mk>
Cc:Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>;Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>

2 attachments (425 KB)

AISC 2023_Call for Papers.pdf; Manipal Logo.jpeg;

Respected Sir

Manipal University Jaipur logo is attached in the mail. We are thankful for the collaboration.

https://jaipur.manipal.edu/

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jaipur.manipal.edu

From: Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>
Sent: 13 July 2023 17:00
To: Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>
Cc: Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>
Subject: FW: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Dear Prabhpreet,

Please share the University Logo and Link with the University St. Kliment Ohridski, Bitola for the International Conference.

Regards

From: Prabhpreet Singh [MU - Jaipur] <prabhpreet.singh@jaipur.manipal.edu>
Sent: Wednesday, July 12, 2023 7:32 PM

To: Dr. Sonu Agarwal [MU - Jaipur] <sonu.agarwal@jaipur.manipal.edu>
Cc: Dr. Jayaram E R [MU - Jaipur] <jayaram.er@jaipur.manipal.edu>; Dr. Santosh Patil [MU - Jaipur] <santosh.patil@jaipur.manipal.edu>; goran.ilik@uklo.edu.mk
Subject: Fwd: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Respected Madam
St. Kliment Ohridski Bitola are organising International conference. It is hereby requested for logo and link. Trail mail for kind consideration.

Get Outlook for iOS

From: Nurten Sulejmani <nurten.sulejmani@uklo.edu.mk>
Sent: Wednesday, July 12, 2023 5:49 PM
To: Goran Ilik <goran.ilik@uklo.edu.mk>; REKTOR Korunovski <rector@uklo.edu.mk>
Subject: CALL for PAPERS: Annual International Scientific Conference UKLO 2023, November 17-18

Respected colleagues,

As partner universities with established relations of bilateral cooperation, it is our distinct pleasure to inform you about a major scientific event *Annual International Scientific Conference 2023*, organized by the University "St Kliment Ohridski" – Bitola, Republic of North Macedonia to be held on 17-18 November 2023, on the occasion of celebrating the World Science Day for Peace and Development.

The Conference topic is "Multidisciplinary Approaches to Sustainable Development Goals". Authors are invited to submit papers on any subject related to and within the scope of the Conference topic. Submissions from academics, researchers, and practitioners at any stage of their career, including PhD students, will be accepted. Selected papers will be published in a special issue of the *Horizons - International Scientific Journal* as a peer reviewed, interdisciplinary, and international journal published by the University "St. Kliment Ohridski" - Bitola, indexed in EBSCO, CrossRef, Google Scholar etc. The language of the Conference is English.

We now invite abstract submissions for the Conference (by 20 September 2023) at the following link:
https://docs.google.com/forms/d/e/1FAIpQLSfxjz1J0DRQy7GYTCm11mdUffQWeDM_dn2gBh9SowUEKu3cSQ/viewform?vc=0&c=0&w=1&flr=0

To that end, we would be very glad to share it with our friends and invite our partner universities to be presented with the institutional logo and link to their institutional web to act as Conference partners and friends. The main benefit for the Conference partners would be the free publication of accepted papers. So, before we share the detailed information about the Conference – time, venue, and program – we would very much appreciate having your consent accompanied by your institutional logo and a link no later than 31 July 2023 submitted via emails: goran.ilik@uklo.edu.mk and nurten.sulejmani@uklo.edu.mk

After that, we will get back to you with further steps as soon as possible.

Looking forward to hearing from you,

Organizing Team
Ms Nurten Sulejmani
IR Officer

University "St. Kliment Ohridski" - Bitola
Bulevar 1 Maj bb
7000 Bitola
Republic of N. Macedonia
+ 389 71 217 422

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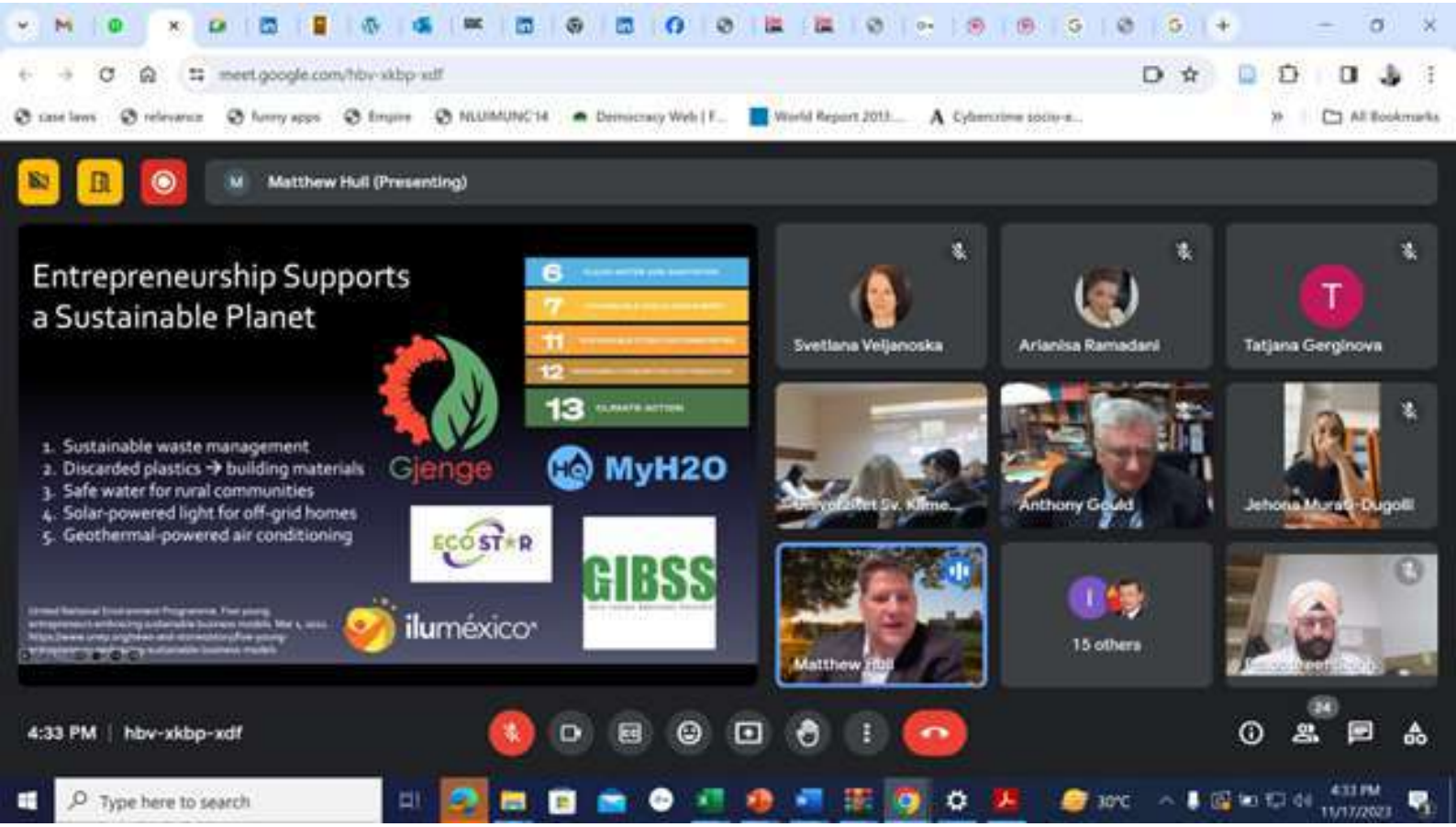
meet.google.com/hbv-xkbp-xdf
Matthew Hull (Presenting)
Entrepreneurship Supports a Sustainable Planet
1. Sustainable waste management
2. Discarded plastics → building materials
3. Safe water for rural communities
4. Solar-powered light for off-grid homes
5. Geothermal-powered air conditioning
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MyH2O
ECOSTAR
GIBSS
iluméxico
Svetlana Veljanoska
Arianisa Ramadani
Tatjana Gerginova
Anthony Gould
Jehona Murati-Dugolli
Matthew Hull
15 others
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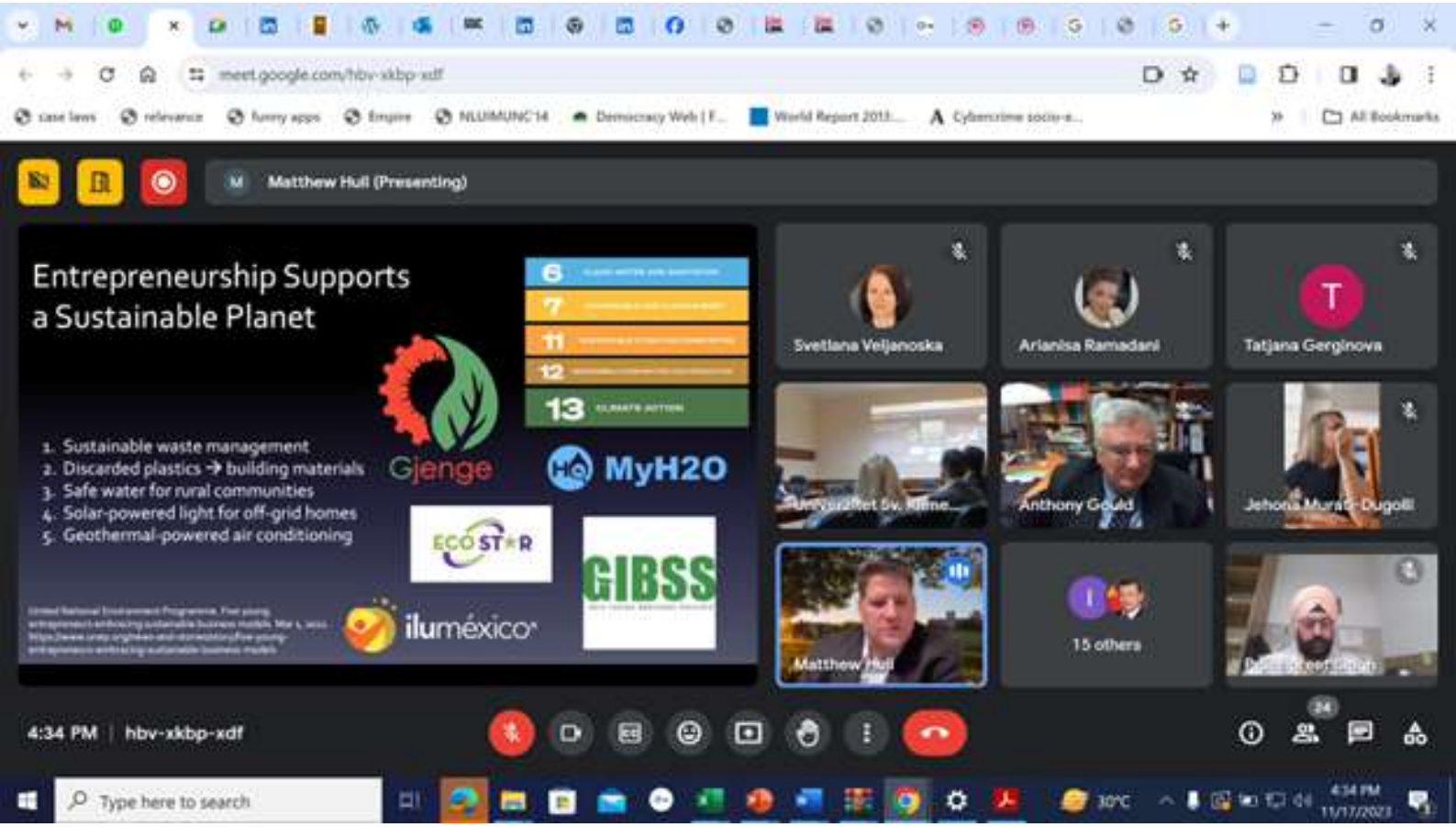
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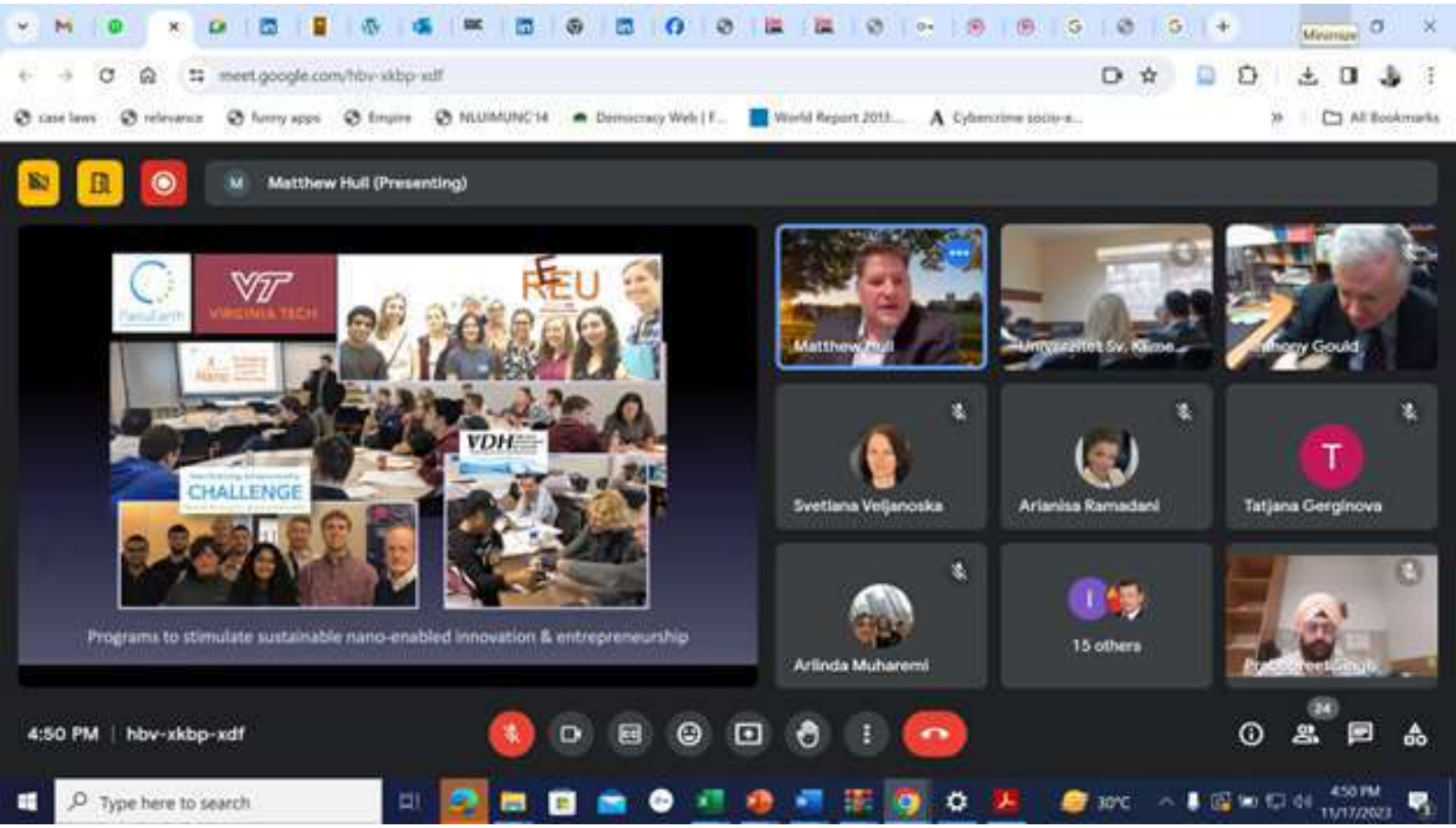
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VIRGINIA TECH
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CHALLENGE
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Programs to stimulate sustainable nano-enabled innovation & entrepreneurship
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Matthew Hull (Presenting)
NanoTechnology Entrepreneurship Challenge (NTEC)
Promote student-led entrepreneurship across NNCI
Flexible support to maximize site engagement
In-kind instrument time
Direct funding (approx$ for instrument time, materials)
Diversity Award (support for underrepresented groups)
Voluntary participation in 7-week NTEC Accelerator
Opportunity to:
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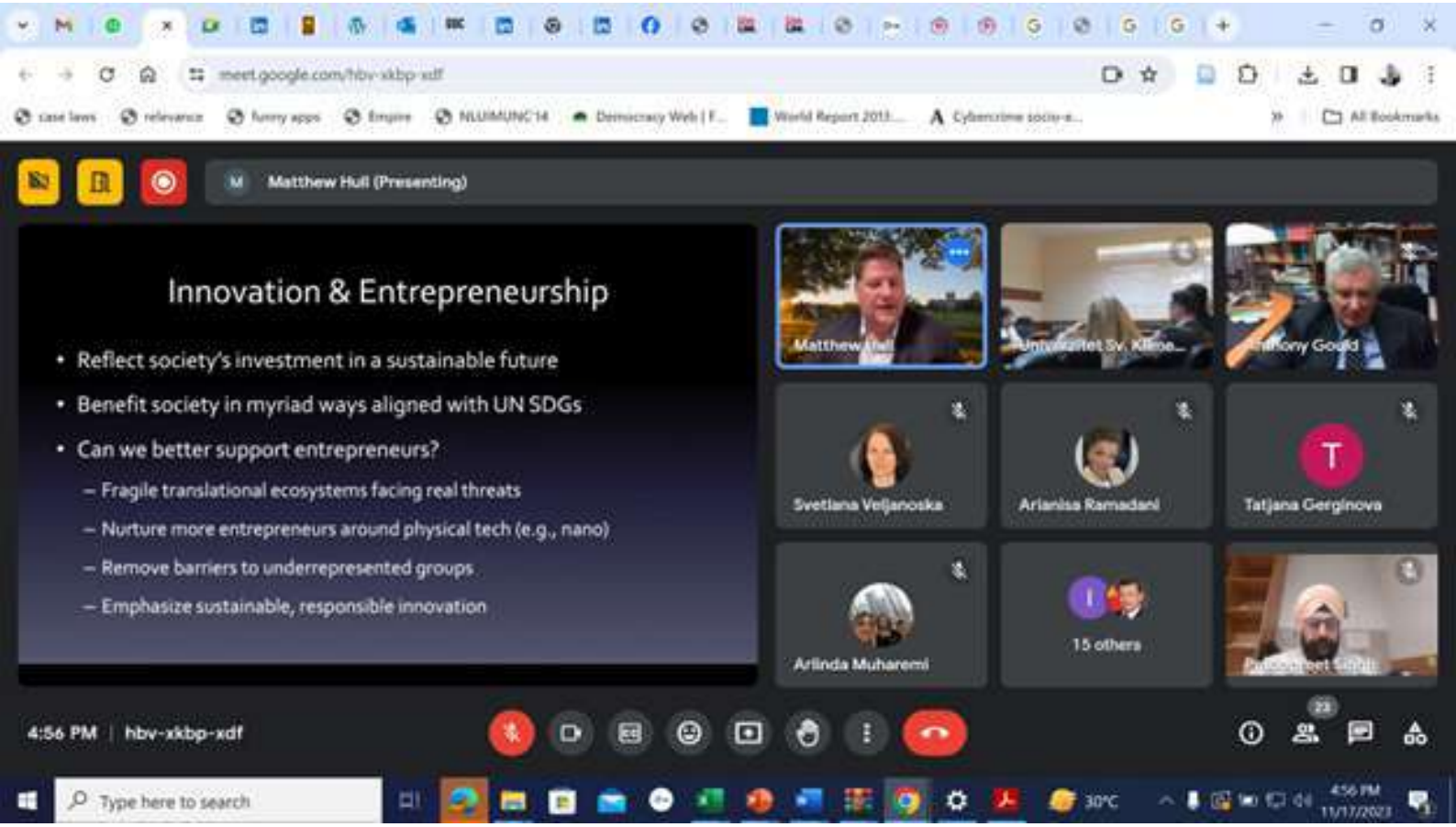
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• Can we better support entrepreneurs?
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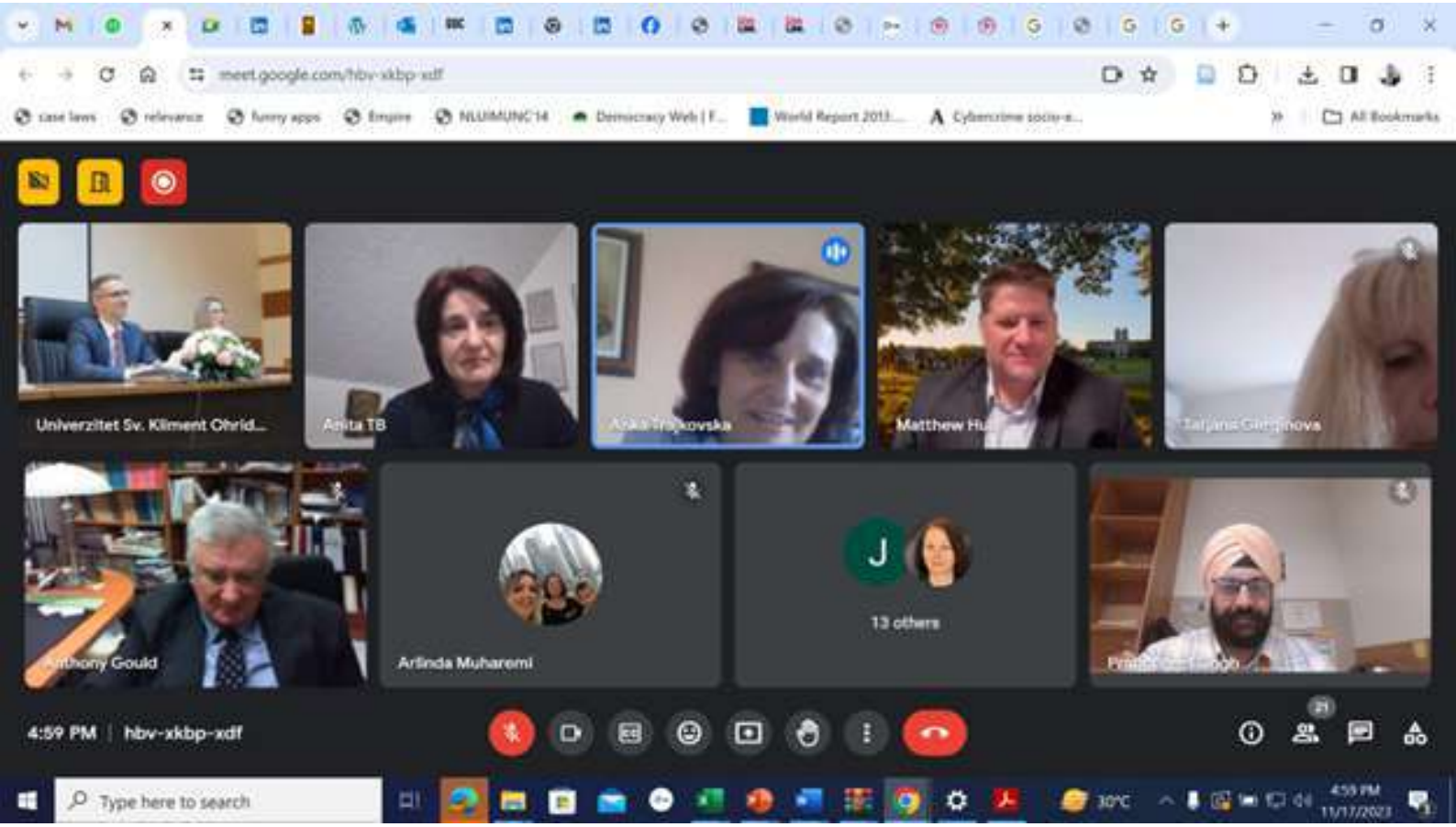
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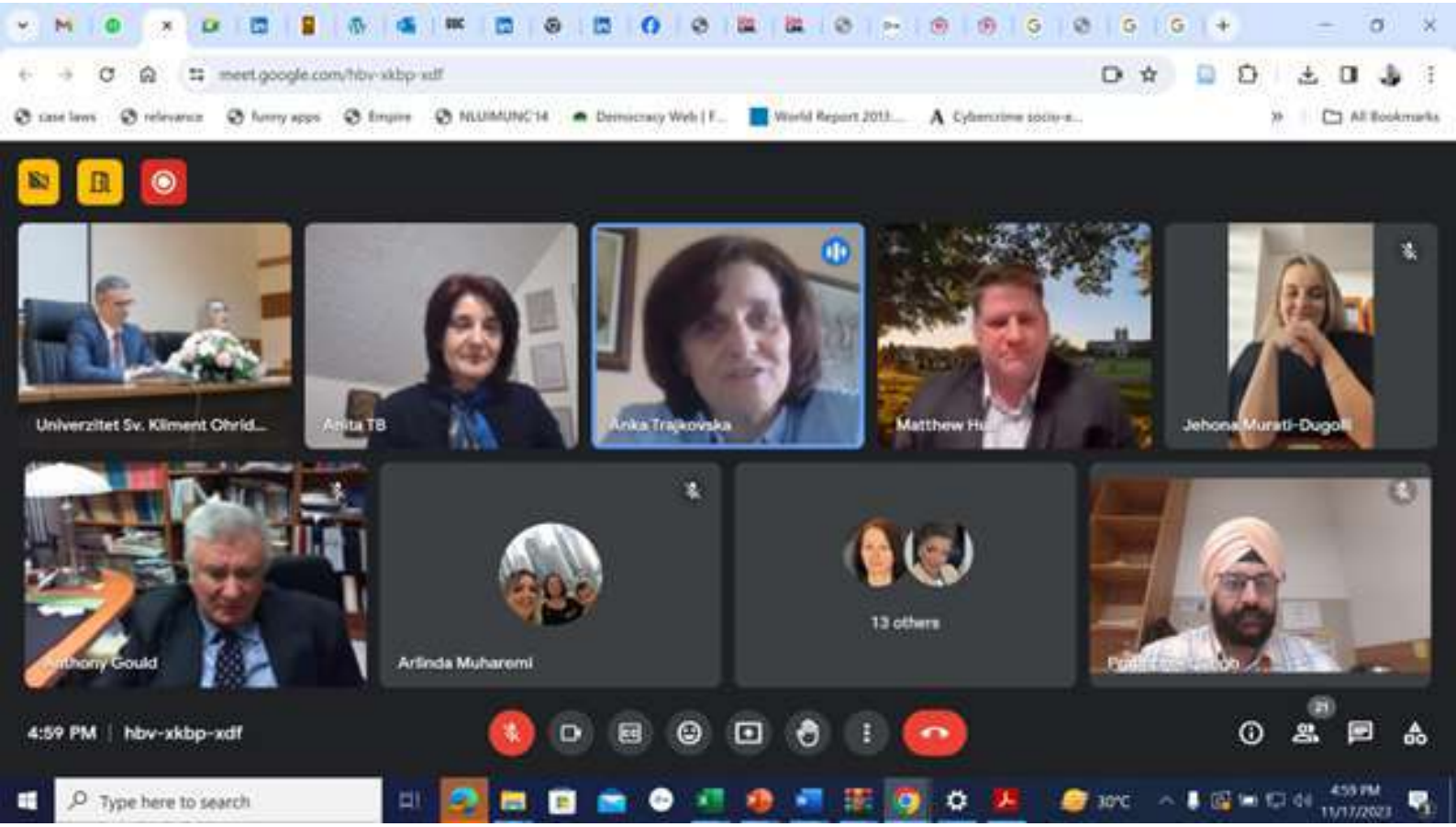
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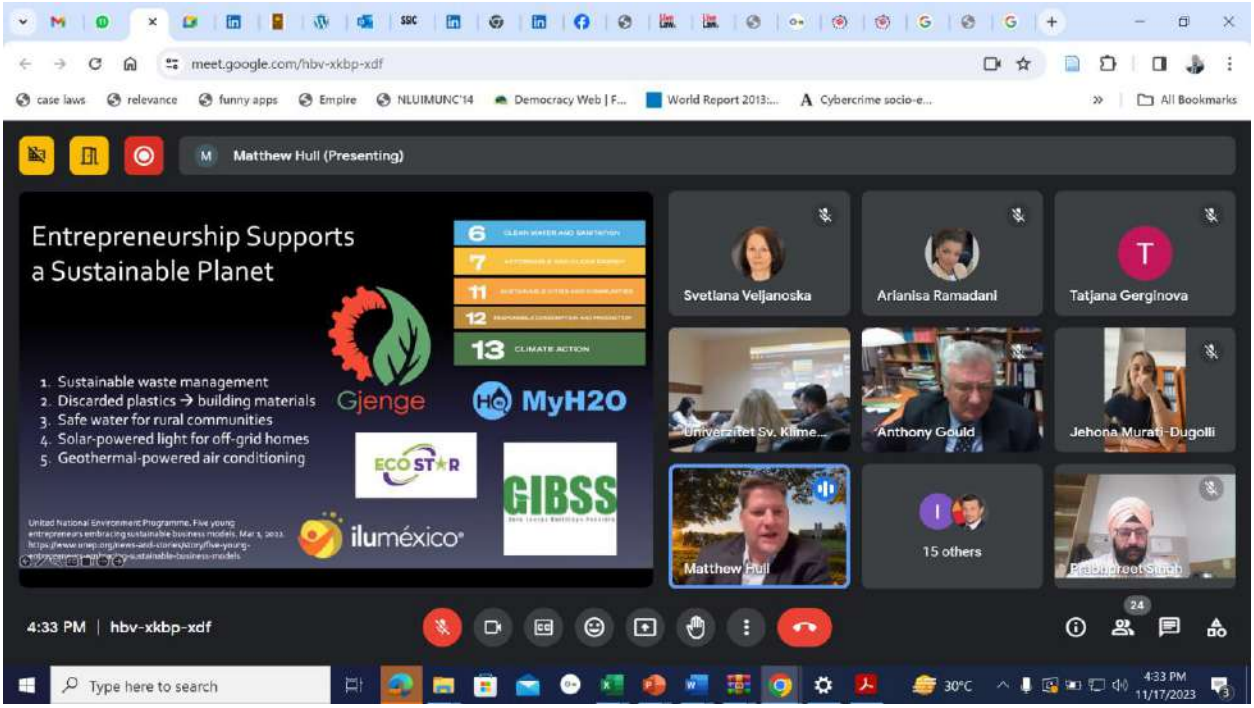
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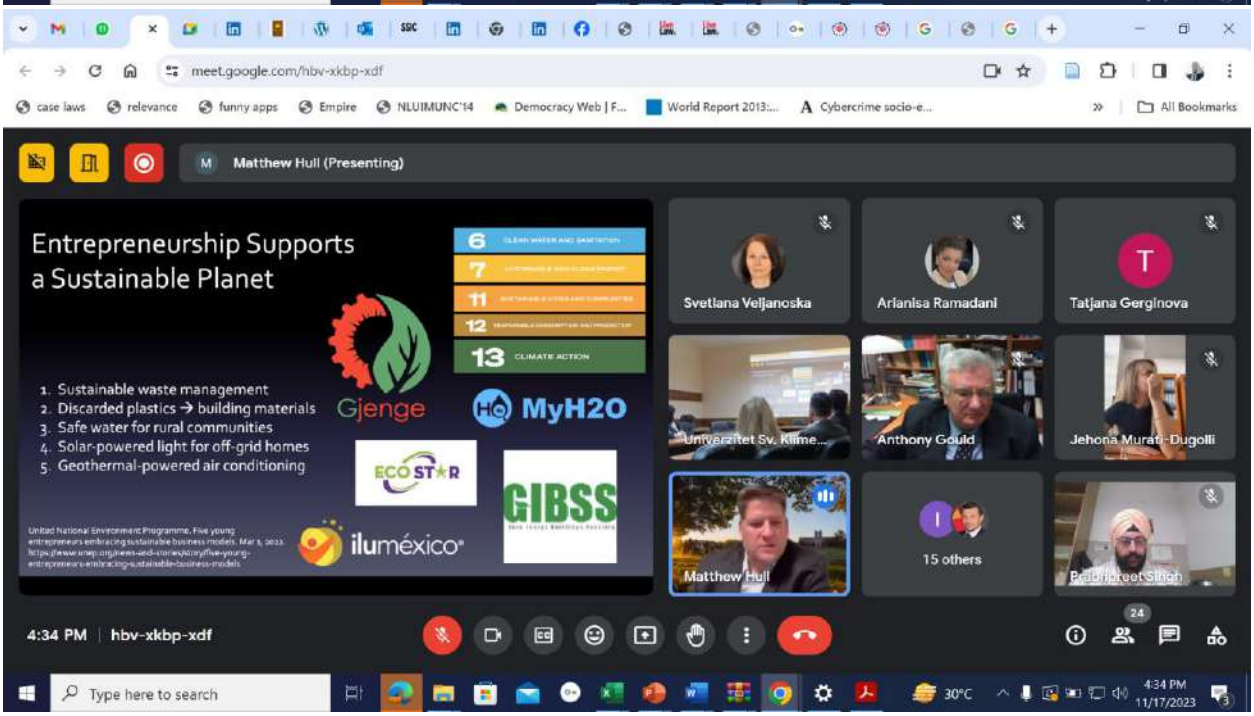
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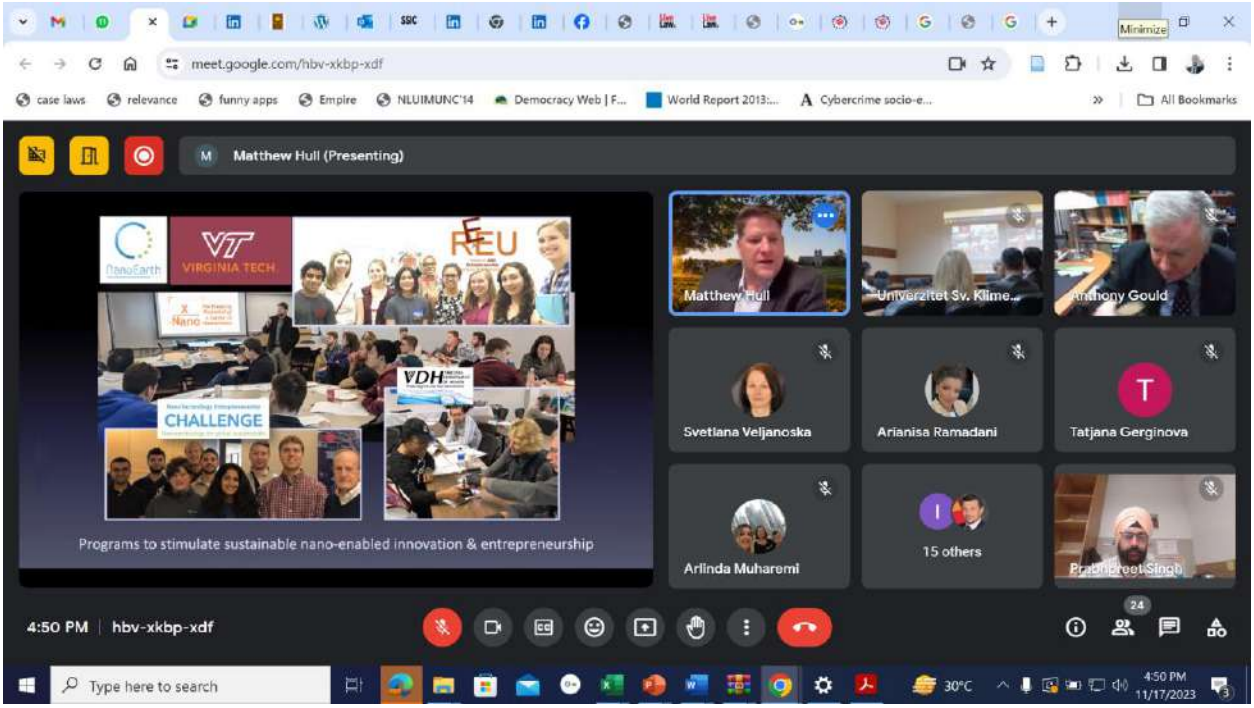
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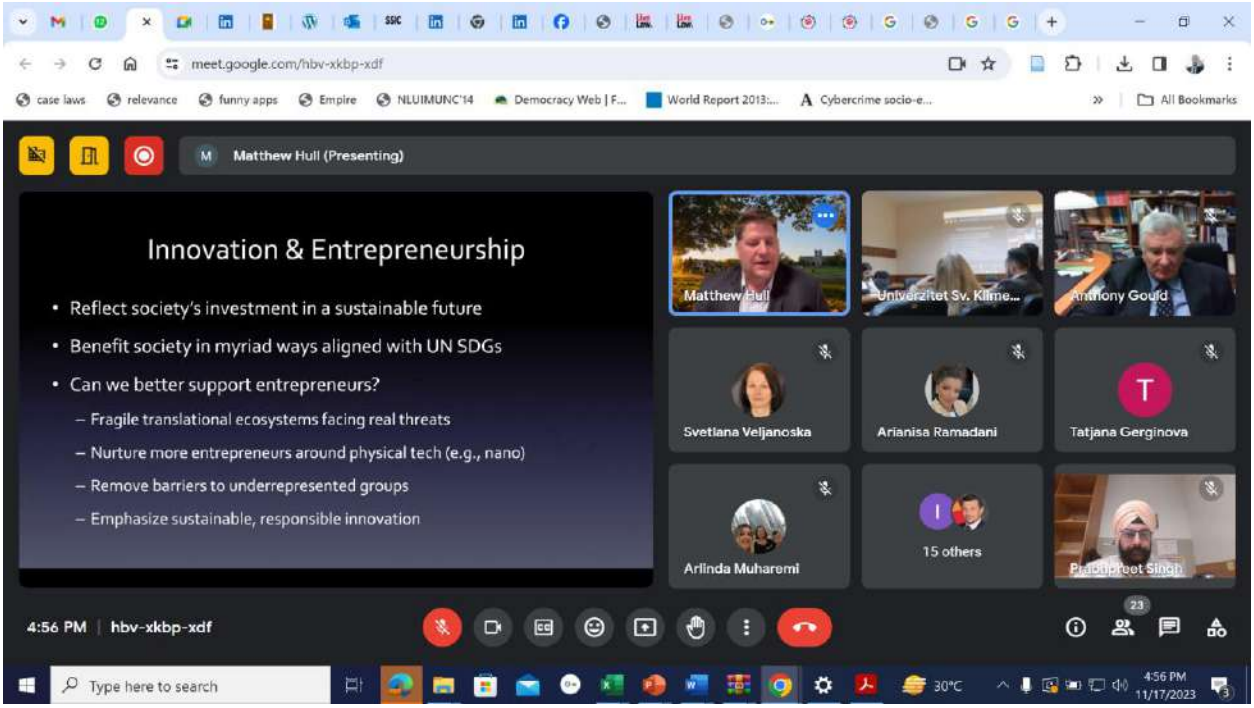
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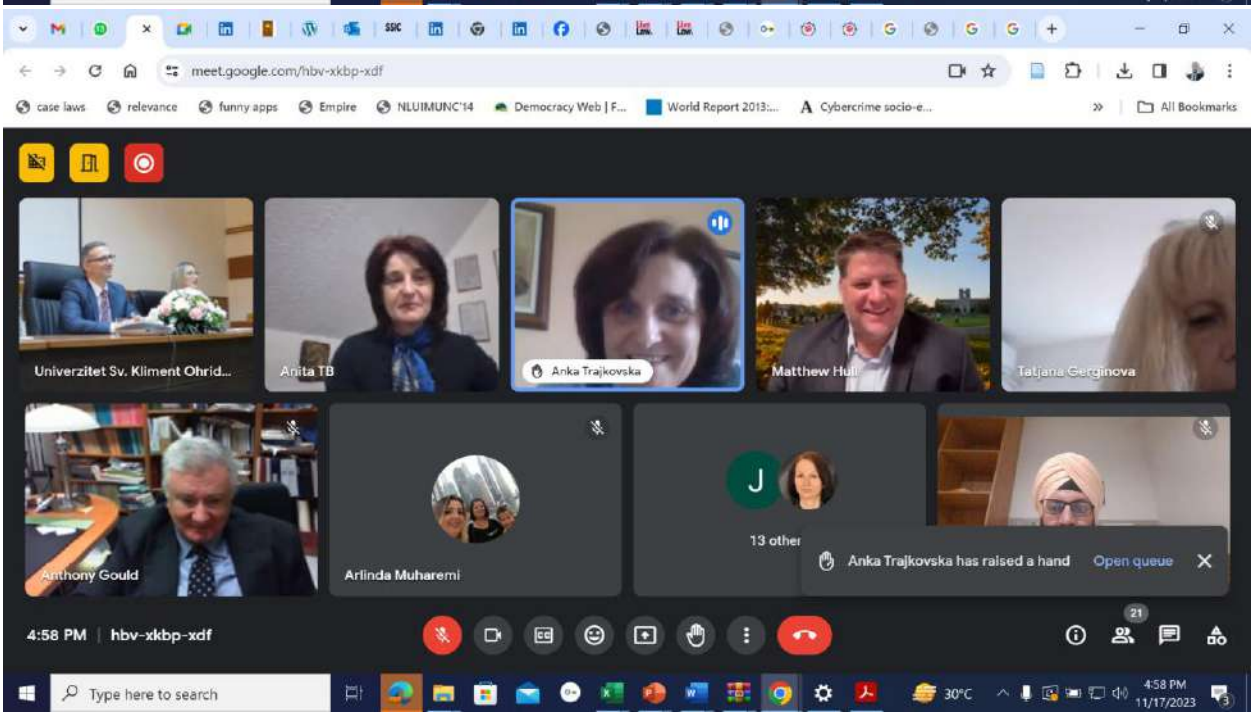
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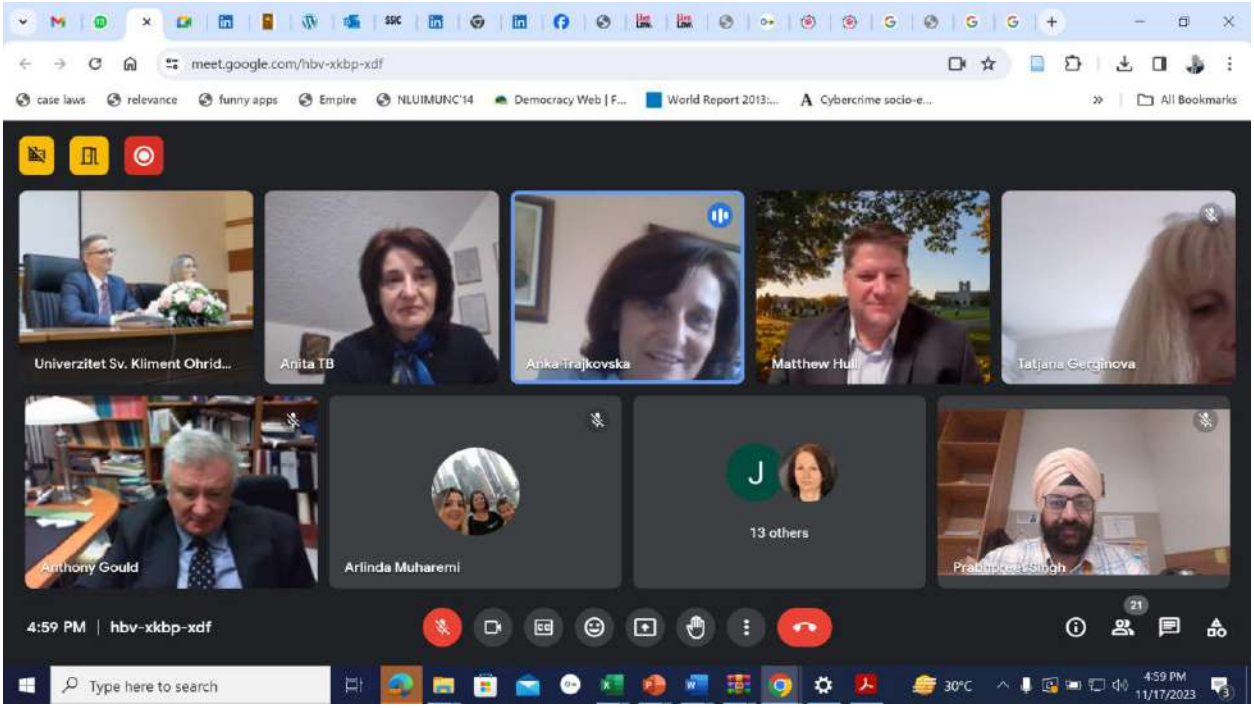

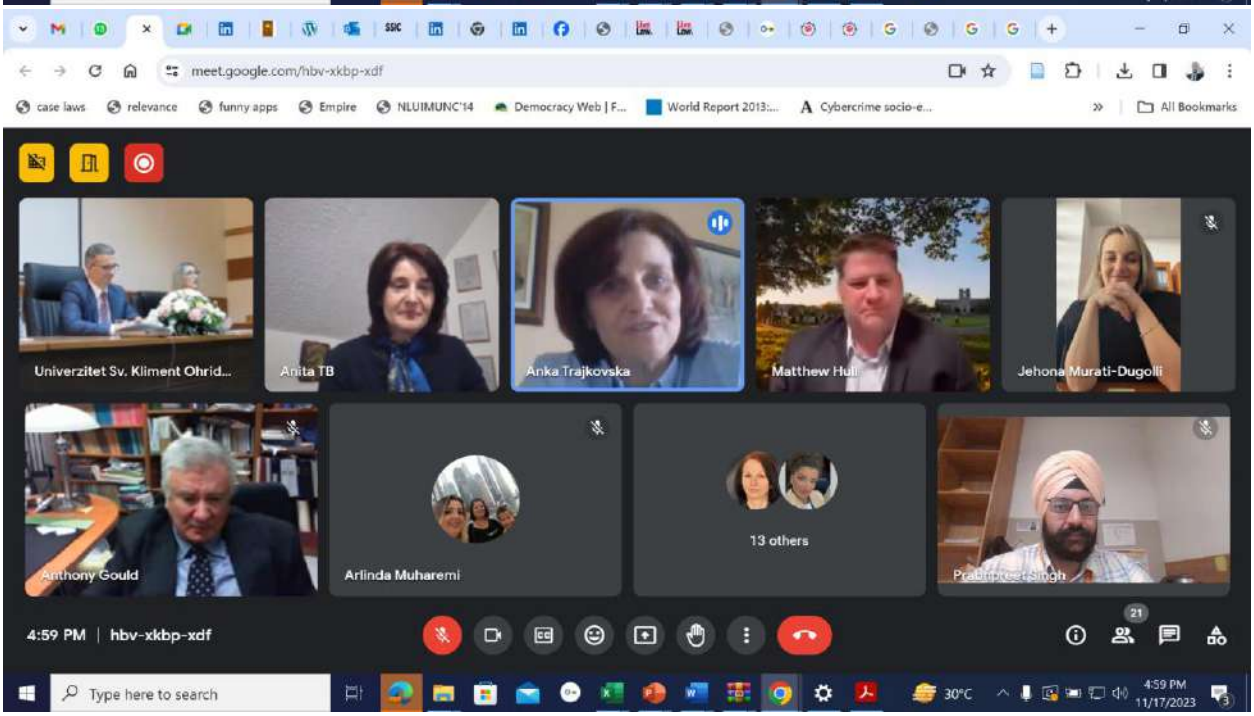

Manipal University Jaipur is a partner university in a major scientific event Annual International Scientific Conference 2023, organized by the University “St Kliment Ohridski” – Bitola, Republic of North Macedonia to be held on 17-18 November 2023, on the occasion of celebrating the World Science Day for Peace and Development. The Conference topic is “Multidisciplinary Approaches to Sustainable Development Goals”. I want to thank Professor Goran Ilik for the kind opportunity and Collaboration.

Also, this is the Second International Conference in which both the Universities are Collaborating. University “St Kliment Ohridski” – Bitola, Republic of North Macedonia was a partner university in 4th International Conference on Smart Systems: Innovations in Computing organized by School of Information Technology, Manipal University Jaipur.

https://lnkd.in/du_vb_mT

UKLO Annual International Scientific Conference 2023 (AISC)

World Science Day for Peace and Development, celebrated annually on November 10th, highlights the significance of science in society and the imperative to engage the wider public in discussions regarding emerging scientific subjects. On this occasion, the University "St. Kliment Ohridski" - Bitola is hosting the *Annual International Scientific Conference 2023* on the following topic:

"MULTIDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT GOALS"

Bitola, Republic of North Macedonia, 17 November 2023
Starting Time: 11:00 CET
Language: English & Macedonian
Place: UKLO Conference Hall (Onsite) & Online
Mode: Hybrid

This AISC offers the chance to mobilize the academy and experts from home and abroad around the issue of science for peace and development with a single purpose - ***changing the world for the better!***

The AISC will focus on discussing the key issues outlined in the UN Agenda 2030. These include eliminating poverty, eradicating hunger, improving health and well-being, ensuring quality education, promoting gender equality, enhancing access to clean water and sanitation, advancing affordable and clean energy, fostering decent work and economic growth, encouraging industry, innovation, and infrastructure development, reducing inequality, building sustainable cities and communities, advocating for responsible consumption and production, addressing climate action, protecting life below water and on land, ensuring peace, justice, and strong institutions, and fostering partnerships to achieve these goals.

AISC Partners:

"Sustainable development requires human ingenuity. People are the most important resource".

- **Dr. Dan Shechtman***

** Dr. Shechtman was awarded with a Nobel Prize in Chemistry in 2011. In 2023, Professor Honoris Causa title was given to Dr. Shechtman at the University "St. Kliment Ohridski" – Bitola.*

Place: UKLO Conference Hall (Onsite)

10:30 – 11:00 Registration of participants

11:00 – 11:30 Opening ceremony (Onsite & Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

Prof. Dr. sc Igor Nedelkovski, Rector of the University "St. Kliment Ohirdski" - Bitola

Prof. Dr. sc Goran Ilik, Vice-Rector for Science at the University "St. Kliment Ohirdski" - Bitola

Dr. Toni Konjanovski, Mayor of Bitola

Dr. Bisera Kostadinovska – Stojchevska, Minister of Culture of the Republic of North Macedonia

Plenary speakers:

11:35 – 12:00

Anthony M. Gould, PhD, Laval University, Canada

Speech: *"Zero-Sum versus Positive Sum: Sustainable Growth through a Change in Mindset"*

(Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

12:05 – 12:30

Matthew S. Hull, PhD Research Professor/Director, NCFL | Virginia Tech ICTAS, USA

Speech: *"Sustainable Entrepreneurship: A Catalyst for the UN Agenda 2030"*

(Google Meet Link: https://meet.google.com/hbv-xkbp-xdf)

12:30 – 12:45 Discussion

12:45-13:00 Coffee break

Moderator: Prof. Dr. Ivona Shushak - Lozanovska

AISC Partners:

#UKLO Annual International Scientific Conference 2023

horizons International Scientific Journal University St. Kliment Ohridski in Bitola

SUSTAINABLE DEVELOPMENT GOALS

PRESENTATION SCHEDULE

17 November 2023

PANEL I

13:00 – 15:15 UKLO Conference Hall (Onsite)

Chair: Prof. dr. sc Ice Ilijevski	
1. Svetlana Nikolovska – EFFICIENCY AND EFFICIENCY OF THE STATE AUTHORITIES AND INSTITUTIONS IN THE SUPPRESSION OF CORRUPTION IN THE REPUBLIC OF NORTH MACEDONIA	13:00-13:15 Onsite
2. Katerina Krstevska - Savovska– PROHIBITION OF TORTURE – MACEDONIAN CRIMINAL LEGISLATION AND COMPARATIVE OVREVIEW	13:15-13:30 Onsite
3. Marina Malish Sazdovska – SUSTAINABLE DEVELOPMENT AS A GLOBAL PHENOMENON	13:30-13:45 Onsite
4. Tatjana Gerginova – GLOBAL SUSTAINABLE DEVELOPMENT	13:45-14:00 Onsite
5. Ice Ilijevski, Ivona Shushak – Lozanovska, Angelina Stanojoska–PROVIDING A "LEGAL IDENTITY" FOR ALL – THE CASE OF THE REPUBLIC OF NORTH MACEDONIA	14:00-14.15 Onsite
6. Gordana Gjorgievska – Nedelkovski, Fatma Bajram, Azemovska – OUR LIBRARY AND SUSTAINABLE DEVELOPMENT GOALS	14:30-14:45 Onsite
7. Liljana Jonoski – A LEVEL OF CONTRIBUTION TO THE AGENDA 2030 THROUGH THE ENFORCEMENT OF GENDER EQUALITY IN NORTH MACEDONIA	14:45-15:00 Onsite
8. Laze Jakimoski – FREEDOM OF AGREEMENT AS A GENERAL PRINCIPLE OF LAW AND ITS LIMITS	14:15-14:30 Onsite
Discussion (Onsite)	15:00-15:15

AISC Partners:

WOXSEN UNIVERSITY

MANIPAL UNIVERSITY JAIPUR (University under Section 2(f) of the UGC Act)

PANEL II

13:00 – 15:15 Online: Google Meet Link: https://meet.google.com/hbv-xkbp-xdf

Chair: Prof. dr. sc Aleksandar Ivanov (aleksandar.ivanov@uklo.edu.mk)	
1. Svetlana Veljanovska – ACCESS TO PUBLIC INFORMATION AS A FUNDAMENTAL DEMOCRATIC RIGHT OF CITIZENS	13:00-13:15 Online
2. Agustina Noeli Vasquez – THE DEVELOPMENTAL ETHOS OF PRESIDENTIAL CANDIDATES IN ARGENTINA: A QUALITATIVE ANALYSIS OF THE 2023 ELECTION DEBATE	13:15-13:30 Online
3. Milan Masat- THE SIGNIFICANCE OF THE EVENTS OF THE SHOAH FOR CONTEMPORARY SOCIETY	13:30-13:45 Online
4. Marina Kalashlinska – THE GOVERNMENT PREPAREDNESS TO RESTRICT THE CIVIL LIBERTIES OF MEDIA AS A CRITERION FOR THE PROLIFERATION OF ANTI-DEMOCRATIC TENDENCIES IN UKRAINE	13:45-14:00 Online
5. Branko Leštanin, Željko Nikač – LEGAL AND ORGANIZATIONAL ASPECTS OF FIGHT AGAINST NARCO-CRIMES IN SERBIA:STATE AND DEVELOPMENT	14:00-14.15 Online
6. Marina Kuzmanovska- THE FAMILY AS A FACTOR IN ENCORAGING OF THE GIFTEDNESS	14:15-14:30 Online
7. Avkash Jadhav – EXAMINING RIGHT TO LIFE AS THE CORE VALUE OF SUSTAINABLE DEVELOPMENT GOALS	14:30-14:45 Online
8. Panche Dameski – CLINICAL EVALUATION OF SURGICAL TREATMENT OF CHERRY EYE WITH MODIFIED MORGAN POCKET TECHNIQUE	14:45-15:00 Online
Discussion (Online)	15:00-15:15

15:15-15:30 CLOSING REMARKS (Onsite and Online: Google Meet Link)

Note: Selected papers presented at the AISC will be published in a special issue of "Horizons - International Scientific Journal", an interdisciplinary, peer-reviewed, and internationally recognized journal published by the University "St. Kliment Ohridski" - Bitola. The journal is indexed in databases such as EBSCO, CrossRef, Google Scholar and more.

Organizer: University "St. Kliment Ohridski" – Bitola, Republic of North Macedonia
Contact phone: +389 47 223 788
E-mail: conference@uklo.edu.mk
Web page: www.uklo.edu.mk

Place: Partizanska 32, Bitola 7000

AISC Partners:

"Sustainable development is the pathway to the future we want for all. It offers a framework to generate economic growth, achieve social justice, exercise environmental stewardship and strengthen governance."

- **Ban Ki-moon**

#UKLO Annual International Scientific Conference 2023

horizons International Scientific Journal University St. Kliment Ohridski in Bitola

SUSTAINABLE DEVELOPMENT GOALS

Conference Partners:

WOXSEN UNIVERSITY

MANIPAL UNIVERSITY JAIPUR
(University under Section 2(f) of the UGC Act)

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AISC Partners:

WOXSEN UNIVERSITY

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(University under Section 2(f) of the UGC Act)

DEPARTMENT OF COMPUTER APPLICATIONS

in collaboration with

DIRECTORATE OF STUDENTS' WELFARE
&
CYPHER CLUB

Visit to Bhamasha Data Center

Outreach Activity

Date of Event: 15th September 2023

Index

S.No.	Activity Heads	Page No.
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2.	Objectives of the Event	3
3.	Beneficiaries of the Event	3
4.	Brief Description of the Event	3
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7.	Schedule of the Event	4
8.	Attendance of the event	4-5
9.	Feedback of the event	5
10.	Link of MUJ Website	6

1. **Introduction of the Event:** This was a visit to BHAMASHAH STATE DATA CENTER organized by the Cypher Club with Department of Computer Application, to increase the knowledge of students.

2. **Objectives of the Event:** This event aimed to enhance knowledge and give exposure to the students of data center that how they store the data, process the data and disseminating data and applications. This would give students a physical knowledge of IT operations.

3. **Beneficiaries of the Event:**

- Computer Applications student and faculty members

4. **Brief Description of the Event:**

With the help of this event students will better understand to work of the company and get familiar with environment of the IT sector. The event took place on 15th September 2023.Event will take place at BHAMASHAH Data Center.

5. **Poster:**

6. Photographs:

Fig 1 Group Pic

7. Schedule of the Event: 15th September 2023

8. Attendance of the Event:
Total Attendee- 240

S. No.	Enrollment No	Student Name
1	211015022	ARYAN PRANAMI
2	211015003	GATIM SAINI
3	221015035	Krishna Biyani
4	221020012	VATSAL GARG
5	221015148	KASHISH GIRDHANI
6	211015056	AMIT KUMAR PATEL
7	221015124	JAYANT SINGH RATHORE
8	211015032	VARUN JINDAL
9	211015082	VIBHOR TIWARI
10	221015149	PUSHPENDRA SINGH RATHORE
11	211015005	VISHAL RATHORE
12	211015010	ROHIT AJARIWAL
13	221015126	VANSH SHARMA
14	221020044	HARSHA JAIN
15	221015139	RITIK RAJ SHARMA
16	221020068	SUPRIO DAS

17	211015058	RAGHAV PUROHIT
18	221020014	DEEPANSH SHARMA
19	211015039	PARIKSHIT KAUSHIK
20	221015099	KSHITIJ KUMAR
21	221020035	AMAN KOTIYAL
22	221020033	KIRTI MAGHALANI
23	221015090	AVIRAL SINGH
24	221020069	SHUBHAM TOMAR
25	221020085	HARSHVARDHAN SINGH RAJAWAT
26	221015168	Charvi Solanki
27	221015143	VEER CHAUHAN
28	221020034	AAYUSHI ROCHLANI
29	221020063	JYOTI KUMARI
30	211015019	DEEKSH SINGH
31	211015072	ANNU BUNKAR
32	211015086	ISHA CHAUHAN
33	221015125	AMAN SHARMA
34	210901065	AMIT PAREEK
35	221020004	HARSH SHARMA
36	221015117	RAUNAK GULATI
37	211015051	RUDRANSH BHARDWAJ
38	211015036	SANCHIT SARDANA
39	221015152	HARSH RAJ NIMODIA
40	211015083	VIDHI GUPTA
41	221020085	HARSHVARDHAN SINGH RAJAWAT
42	211015023	YOGESHCHANDRA PANT
43	211015093	Preeti Guwalani
44	211015091	TANISHKA GUPTA
45	211015014	PULKIT SHARMA
46	211015080	AMAN YADAV
47	221020043	SIDDHARTH SHARMA
48	221015140	NIKHIL PRAJAPATI
49	221020050	ABHAY SHANKAR
51	221015104	Simran
52	211015084	ANUJ GUPTA
53	221020048	DEEPAK SHARMA
54	221015083	Rakesh S
55	221020041	RAHUL SAINI
56	221015096	MANVENDRA SINGH
57	221015116	PRIYANJALI BOTHRA
58	221020002	PRIYANKA SINGH
59	221020072	RAUNAK BOHRA
60	221015132	AYUSH BATRA
61	211015071	JAY SHARMA
62	211015090	ROSHAN BADAYA
63	221020070	JATIN KUMAR
64	211015066	GAUTAM SAMBLANI
65	211015067	RAGHAV REWARIA
66	221015012	Karni Singh

67	221020007	RITIK MITTAL
68	221020047	SOURABH PARWAL
69	221015089	BHARATKUMAR SOMARAM CHAUDHARY
70	221020057	CHOUDHARY NARESH
71	221015127	ANANYA PUROHIT
72	221020078	BHAVESH DEVJIBHAI VARMA
73	221020024	SHYAM GUPTA
74	211015010	ROHIT AJARIWAL
75	221015154	ARTHAV BHDAYA
76	221020065	SAGAR JAIN
77	221020053	PIYUSH DIXIT
78	221020087	PARVEN KHATWA
79	221020083	GAUTAMI SINGH JADOUN
80	221020032	AYUSH VIJAY
81	221020021	ARIJEET DEY
82	221015122	Yash
83	221020006	ANUBRATA MALLIK
84	211015015	MOHIT SINGH JAKHAR
85	221020036	DEEPAK CHOUDHARY
86	211015073	VIRAJ SHARMA
87	221015136	SAMUNDRA SINGH BHATI
88	211015017	ROOPAK MALLIK
89	211015029	SYED MOHAMMAD MEEZAAN CHISHTY
90	221015118	SREEYA ARLAGADDA
91	211015030	AKSHAT SONI
92	221020009	MOJ LADANI
93	221015130	SIDDHARTH KHIRWAL
94	221015141	ANISHA BADIWAL
95	211015033	TANISHKA SANJAY KAPIL
96	221020060	BHARTENDU KUMAR
97	221020027	HIMANSHU JANGID
98	211015007	PRANSHUL VIJAYVERGIA
99	211015079	ARSSH PRATAP SINGH
100	221020017	PRITAM SWAMI
101	221015121	MOHIT SINGH NARUKA
102	221015103	ABHISHEK PILLAI
103	211015077	MUSKAN GOYAL
104	221020074	CHENA RAM BIJARNIYA
105	221015097	BIPUL SARKAR
106	221015147	MAYANK PURI GOSWAMI
107	221020031	TANIYA SONI
108	221020084	OMPRAKASH JANGIR
109	221020075	AYUSH RAWAT
110	211015040	RISH0H JAIN
111	221020011	RAHUL SAINI
112	211015024	OM SHREYA
113	221020001	DINESH KUMAR ROCHANI
114	211015009	JATIN SADHNANI

115	211015004	ADITI BENDRE
116	221020080	SHASHANK JANGIR
117	221020081	RAMESH KUMAR
118	221020029	VINITA MATHUR
119	211015042	KULWANT SINGH RATHORE
120	211015014	PULKIT SHARMA
121	221020025	TEJARAM GURJAR
122	221015146	PRIYA JAIN
123	221020056	YASH KHARE
124	221020058	RITIK PATWA
125	221020010	SOUGATO ROY
126	211015038	KHEMENDRA SINGH KHANGAROT
127	211015087	PRATYAKSH BHANDARI
128	211015005	VISHAL RATHORE
129	221020073	SHREYANSH PANWAR
130	221015123	RUHUL RASHID ANSARI
131	221020086	RAGHAV BHAYANA
132	221020077	AYUSH SHARMA
133	221020061	SHUBH SRIVASTAVA
134	221015067	Avinash Saini
135	211015002	SUNIL KUMAWAT
136	211015011	JATIN PATTNAIK
137	211015016	KAVISH VINEET DESAI
138	211015021	RAKSHA AGARWAL
139	221015150	DIVYANSHI KEDIA
140	221020083	GAUTAMI SINGH JADOUN
141	221015144	RISHI KHURANIYA
142	221015092	MANAN KUMAWAT
143	221020074	CHENA RAM BIJARNIYA
144	221020049	ROHIT SOLANKI
145	221020046	ANTIMA PAREEK
146	211015069	VIDHI KHANDELWAL
147	221020030	APEKSHA KUMAWAT
148	211015084	ANUJ GUPTA
149	211015050	MANI RATNAM
150	211015057	RAHUL CHOUDHARY
151	211015064	VAIBHAV SAINI
152	211015078	SURYAANSH CHANDRA JAIN
153	221020051	SHIVAM TIWARI
154	221020059	INDERJEET YADAV
155	211015041	HARSH SARASWAT
156	221015146	Priya Jain
157	211015076	SATYAM CHOURASIA
158	221020052	SEJAL JAIN
159	221020003	AKANKSH PADGETWAR
160	221015133	NIKHIL SINGH CHAUHAN
161	221020042	ASEEM MALPANI
162	211015035	SHIVAM TAMBOLI

163	221015063	Harsh Vardhan Gurjar
164	221015153	KEWAL KRISHAN
165	211015085	RITAM MAITY
166	211015065	HARSH SHARMA
167	221020088	YASH SHARMA
168	211015062	PRAVEEN RATHORE
169	211015061	ANANYA GOYAL
170	211015046	ADITYA GUPTA
171	211015006	VATSAL BHUVA
172	211015027	BHUVAN MAHESHWARI
173	221020012	VATSAL GARG
174	221020045	VIJIT KUMAWAT
175	221015114	DIYA MURANI
176	211015037	SAMARTH KUSHWAHA
177	221020055	SHUBHAM KUMAR CHOUDHARY
178	221015142	SABOOR HAMDAAN
179	221015036	Dinesh Surthar
180	221020076	JAI SHARMA
181	211015044	DIYA SHARMA
182	221015088	GAUTAM CHOUDHARY
183	221015147	Mayank Puri
184	211015092	MANYA SHARMA
185	221020038	SAGAR KUMAR
186	221020071	MAHIPAL SINGH
187	221020010	SOUGATO ROY
188	211015049	SNEHA
189	221020023	AMAN SHARMA
190	221015129	DIPESH KUSHWAH
191	221015137	RITIKA SHARMA
192	221020066	ROHIT SWARNKAR
193	221015128	VIVEK SABNANI
194	221015115	ANIRUDDH SINGH
195	221015131	KRISHNA GEHANI
196	211015068	ACHINT GUPTA
197	211015015	MOHIT SINGH JAKHAR
198	211015053	LAKSHIT SHARMA
199	221020067	KUNAL SAHA
200	221020005	SAURABH AJAY BANSAL
201	221020020	HEMANG KUMAWAT
202	211015048	UTKARSH VIJAY TRIPATHI
203	211015043	HRICKBEDI DAS
204	211015089	SWAYAM JAIN
205	211015060	PRIYANSH KHANDELWAL
206	221020079	RITI SHARMA
207	221020026	DEEPAK KUMAR DHAKA
208	221015094	ADITYA BHATT
209	221020022	RITESH ANAND
210	211015017	ROOPAK MALLIK

211	211015054	REHANSH OJHA
212	211015013	ASHWANI CHHIPA
213	221020019	ADITYA SINGH
214	221015122	YASH BHATI
215	221015095	HARSHVARDHAN SINGH SHEKHAWAT
216	211015063	VARUN SHARMA
217	211015031	NAMISH TULI
218	221020082	AYUSH SHARMA
219	211020004	KUMARI AGRATA
220	211015088	PRIYANSHU KHALIYA
221	221020040	HARSH JANGID
222	221015093	MANVENDRA SINGH RATHORE
223	221015106	PRINCE KUMAR SAMARIYA
224	221015091	MANVENDRA SINGH RATHORE
225	221015145	PRINCE YADAV
226	221015144	Rishi Khervania
227	221020037	MANU SHARMA
228	221015120	RYAN CHHABRA
229	221020016	ABDULLAH RAHMAN
230	221015087	PRANVEER SINGH GAUR
231	211015081	ASHWINDER SINGH ARORA
232	211015008	HITEN JAIN
233	211015070	YUVRAJ PURI
234	211015012	GOVIND SUROLIYA
235	221020039	PRIYAM
236	221020064	KETAN KARTIK
237	221015091	Manvender Rathore
238	221015105	ANUSHKA SHARMA
239	221015155	BHUWAN GARG
240	211015085	RITAM MAITY

9. **Feedback of the Event**: Student felt immense pleasure by attending the session at data center and experiencing the technology presented over data center

Dr. Devershi Pallavi Bhatt (HOD)

MANIPAL UNIVERSITY
JAIPUR

INSPIRED BY LIFE

FACULTY OF DESIGN

International Conference on Sustainable Development for Heritage and Built Environment

22/06/2023 – 23/06/2023

Head, Department of Interior Design
SD&A, Faculty of Design
Manipal University Jaipur

Content of Report

1. Introduction of the Event
2. Objective of the Event
3. Beneficiaries of the Event
4. Brief Description of the event
5. Photographs
6. Poster of an Event
7. Schedule of the Event
8. Attendance of the Event

1. Introduction of the Event

The conference is inspired from the critical challenge of human, environmental, heritage and built sustainability concerning the present and future generations in a global-scale context. This theme emphasizes the strong foundation that is provided by using research to inform our everyday practices, policies, and analytical approaches. This interdisciplinary forum is for scholars, teachers, and practitioners from the built environment professional discipline who share an interest in—and concern for— sustainability in an holistic perspective, where environmental, cultural, economic and social concerns intersect. It will provide a platform for various individuals to connect the past and present and develop solutions to a more universal and environmentally friendly approach towards built environment.

The conference will include topics such as

(i)Sustainable approach to design in built environment,

(ii)Sustainability & built Heritage,

(iii)Conserving Built Heritage,

(iv)Sustainable Policies for Environmental and Infrastructure Planning,

(v)Earth and Environmental Planning & Design

2. Objective of the Event

This conference was a gathering of minds dedicated to addressing the pressing challenges of sustainability that affect our world today and tomorrow. It recognized that sustainability is a multifaceted concept that requires interdisciplinary collaboration and rigorous research. By bringing together scholars, educators, and practitioners, the conference facilitated the exchange of ideas and the development of solutions that promote a more sustainable, resilient, and environmentally friendly built environment.

3. Beneficiary of the event

This interdisciplinary forum is for scholars, teachers, and practitioners from the built environment professional discipline who share an interest in—and concern for— sustainability in an holistic perspective, where environmental, cultural, economic and social concerns intersect.

4. Brief Description of the event

The conference was hosted by Department of Interior Design and School of Architecture and Design, Faculty of Design at Manipal University Jaipur. This interactive and engaging event is tailored exclusively for our researchers, as part of our commitment to foster continuous learning,future research opportunities. The presentations focused on sustainability as the prime agenda and paved way for the researchers to present their work at an international level.

5. Photographs of the Event

Snippets of the Conference

6. Poster of the event

7. Schedule of the event

Time	Event	Speaker
11:00 – 11:30 AM	Opening speech	Dr Richa Jagatramka
11: 30 – 11:35 AM	Welcome address	Dr Madhura Yadav
11: 35 – 11:45 AM	Introduction of international speaker	Ar Himangshu Kedia
11: 45 AM – 12:45 PM	Presentation by Dr Muge	Dr Muge
12: 45 – 01:00 PM	Q & A session	
01:00 – 01:05PM	Vote of Thanks	Ar. Himangshu Kedia

Meeting Link :

https://teams.microsoft.com/l/meetup-join/19%3ameeting_MmRjNjZiN2ItMTc1NS00YmJlLTkwMTItMzBiYTVjNTI0YTRh%40thread.v2/0?context=%7b%22Tid%22%3a%227d0726e8-bf4b-4ac1-99f1-010fb11f1d3f%22%2c%22Oid%22%3a%2216be8839-914f-456c-9836-e6b3ba8fa2f9%22%7d

8. **Attendance of the Event**
   Total attendees – 28 participants from MUJ and outside

Sl.no	Name	Organisation
1	Dr. Richa Jagatramka	FOD
2	Megha Prabhu K	FOD
3	Dr. Sampath Kumar Padmanabha Jinka	FOD
4	Dr. Madhura Yadav	FOD
5	Dr. Anantkumar Dada Ozarkar	FOD
6	Dr. Subhash Chandra Devrath	FOD
7	Nisha Nelson	FOD
8	Preethi Agrawal	Practicing Architect and PhD scholar
9	NITIKA TORVI	Christ University
10	Subhadha B	Christ University
11	Himangshu Kedia	FOD
12	Rushikesh Kolte	MNIT
13	Dr. Sunanda Kapoor	FOD
14	Ananya Tripathi	AKTU - GCA
15	Kinzalk Chauhan	FOD
16	Ritu Sharma	FOS – Phd Scholar
17	Rimjhim Swami	FOD
18	Ayushi Sharma	FOD
19	Apoorva Agarwal	FOD
20	Muge Fialho Leandro Alves Teixeira	QUT Australia
21	Deeksha	MNIT
22	Siddharth Mishra	FOD
23	Akshay Gupta	FOD
24	Ritu Sharma	FOD
25	Neha Saxena	FOD
26	Antima Kuda	MAHE Dubai
27	Raunak Prasad	FOD
28	Ashutosh Saini	FOD

Head, Department of Interior Design
SD&A, Faculty of Design
Manipal University Jaipur

ScienceDirect

Journal of Energy Storage
Volume 68, 15 September 2023, 107714

Research papers

Beeswax as a potential replacement of paraffin wax as shape stabilized solar thermal energy storage material: An experimental study

Pushpendra Kumar Singh Rathore [a], Krishna Kumar Gupta [b], Bhaskar Patel [b], R.K. Sharma [c], Naveen Kumar Gupta [d]

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Highlights

- Beeswax/Bentonite/graphite based SSCPCM for thermal energy storage was prepared.
- SSCPCM shows substantially good thermal energy storage capacity.
- Beeswax based SSCPCM shows excellent heating rate and thermal conductivity.
- SSCPCM was thermally, chemically and physically stable.

Abstract

Thermal Energy Storage (TES) using paraffin wax as Phase Change material (PCM) has been widely used for solar to thermal energy conversion and storage application. Being petroleum by-product, production of paraffin wax have embodied environmental impact and high carbon footprint. Beeswax can replace paraffin's as one of the clean, sustainable, eco-friendly and potential TES PCM. However, TES potential of Beeswax was not investigated thoroughly in previous literatures. Also, limited study has been found which evaluates solar to thermal conversion potential of Beeswax. This study presents a comprehensive analysis of TES performance of Beeswax supported by Bentonite clay and loaded with Graphite was evaluated. Bentonite clay was used as supporting material and Graphite powder is used as additive in varying percentage to form Shape Stabilized Composite Phase Change Material (SSCPCM). SSCPCM was initially investigated for anti-leakage behaviour and was found that Bentonite can hold maximum 40wt% of Beeswax without leakage above phase transition temperature. Thermal energy storage parameters, thermal degradation, solar to thermal conversion performance, chemical stability, surface morphology, and thermal conductivity were evaluated. Bentonite and graphite has shown good morphology to form SSCPCM samples. Also, SSCPCM has proved to be chemically and physically stable thermal energy storage material. Melting enthalpy of 101.79, 100.66, 98.80, 100.43, 96.51, and 105.01 at melting point of 59.43, 58.88, 58.12, 57.98, 57.36, and 57.11 of SSCPCM-0, SSCPCM-1, SSCPCM-3, SSCPCM-5, SSCPCM-7, and SSCPCM-9 was obtained. Adding Graphite has reduced supercooling of SSCPCM samples maximum by 84.13%. Increasing additives in PCM improves heating rate and thermal conductivity of the SSCPCM.

Introduction

Last decade have seen continuous rise in energy demand due to increase in population, globalization, and improvement in living standard. Most of this demand is fulfilled by fossil based fuels such as coal and crude oil. This leads to over-exploitation of limited reserves of fossil fuels causing rapid depletion and excessive greenhouse gas emissions. To mitigate these challenges renewable sources of energy has shown a significant capacity enhancement [1]. Due to abundant availability, low cost, and negligible emissions renewable sources of energy can play a decisive role against climate change. Among various renewable sources, solar energy is one of the major renewable source of energy available to the mankind almost at every location of the planet earth [2]. To harness solar energy various solar technologies such as solar photovoltaic, solar collectors, soar concentrator, solar still, and solar dryers were used for varieties of applications. However, solar energy suffers with serious limitations of limited availability by location, time, and power. These drawbacks leads to poor utilization and low efficiency of solar thermal technologies. To overcome these drawbacks Solar Thermal

Energy Storage (STES) can play a vital role in improving energy efficiency and utilization rate of solar thermal technologies [3].

Thermal Energy Storage (TES) is a technique of storing excessive heat energy in a material and utilizing it as and when it is needed. TES can be classified into two categories (a) Sensible heat storage (b) Latent heat storage [4]. Sensible heat storage is one of the oldest technology of storing thermal energy by rising the temperature of the object whereas in latent heat storage the material undergoes phase transformation to store thermal energy. Phase transformation (solid-liquid and liquid-solid) gives advantage of high energy density at minimum temperature change in comparison to sensible heat storage materials. Latent heat storage using Phase Change Materials (PCM) is the widely used technique for TES for various applications. PCM are the materials which stores thermal energy while undergoing phase transformation (solid-liquid) and releases it by again undergoing phase transformation (liquid-solid) [5]. The storing (charging) and releasing (discharging) of thermal energy in PCM takes place at almost constant temperature or in a narrow temperature range. Additionally, easy availability in large temperature ranges has increased feasibility of latent heat TES technology.

Varieties of PCM are available for TES. However, the most commonly used PCM are paraffin. Paraffin are saturated alkanes having chemical formula as C_nH_{2n+2}. Where n is number of carbon atoms. The melting point of alkanes increases with increase in number of carbon atoms. Paraffin possess various merits such as large melting temperature range, high latent heat, and good storage density with respect to mass [6]. Generally, for building applications the PCM used are having melting temperature range of 20°C to 40°C. However, the melting range of PCM varies depending on climatic temperature of the location [7]. Paraffin suffers with two major drawbacks, first is there low thermal conductivity and second is that they are produced from petroleum products, which is the major producer of harmful emissions. Various attempts were made to overcome the first drawback of low thermal conductivity of paraffin. Loading of Al_2O_3 nanoparticles in paraffin wax was done to improves its thermal conductivity [8]. Result suggest that the thermal conductivity of paraffin wax increases when loaded with Al_2O_3 nanoparticle in liquid state whereas it decreases in liquid state. A study investigates the effect of loading of multi-walled carbon nanotubes, graphene nanoplatelets, and aluminum oxide nanoparticles in PCM [9]. The results shows that after few thermal cycles significant coagulation and deposition of nanoparticles occurs. Also, they suggest that long term stability of paraffin loaded with nanoparticles remains a challenge. Graphene nanoparticles were dispersed in paraffin/water emulsion for enhancing thermal conductivity and photo-thermal performance [10]. Another study shows the effect of loading copper nanoparticles in PCM when subjected to external magnetic field [11]. Some commonly used nanoparticles to improve the thermal energy storage characteristics of the paraffin are graphite [10,12], Al_2O_3 [13], copper nanoparticles [14],

TiO_2 [15], and carbon nanotubes [16]. 1D nanoparticles and 2D nanoparticles are widely used to develop PCM composite with improved thermal, physical, and chemical performance [17]. 1D materials such as Carbon Nanotubes (CNT), Silver nanowires, and Copper nanowires were used as additives in PCM to improve thermal conductivity [18]. Among these 1D materials CNT (SWCNT and MWCNT) is exhaustively analyzed to improve PCM performance. 2D nanomaterials based PCM composites are widely used to improve thermal performance of the PCM [19]. 2D materials have weak van der Waals force and strong covalent bond between in-plane atoms. Widely used 2D materials are Graphene [20], Boron nitride [21], Graphite [22], Nanoclays and MXene [23]. Recently, Mxene based PCM composites are increasingly explored because MXene exhibits high surface area, high thermal conductivity and powerful solar absorption capacity. However, none of these materials were used to evaluate solar to thermal energy storage and conversion of Beeswax. Thus, it can be viewed that there are several methods available which can be considered potential technologies for improving low thermal conductivity of the paraffin. However, none of the articles have discussed the second major drawback i.e. paraffin are the petroleum based products having high carbon footprints. Being petroleum by-product the production and processing of paraffin's is energy intensive and can negatively impact the energy savings measures taken care due to TES using paraffin. A study suggested that the use of PCM based on fossil fuels such as paraffin in buildings is not recommended because of various environmental impact [24]. Environmental risk related to paraffin are also higher especially for the marine environment [25]. Another study suggested to replace traditional fossil based PCM by some ecological friendly PCM in buildings after conducting a life cycle assessment analysis of PCM [26]. A study found that replacing petroleum based paraffin by eco-friendly PCM can reduced 45%–50% greenhouse gas emissions [27]. Thus, it is understood that there is a need to search alternative of petroleum based paraffin wax as thermal energy storage material to reduce the embodied environmental impacts during production and processing [28].

Therefore, the objective of this study is to evaluate the potential of naturally occurring PCM for STES. One of the eco-friendly naturally occurring PCM is Beeswax (BW). Beeswax is produced from bee's hives of honeybees. It is organic non-paraffin PCM. Good thermal energy storage capacity [29,30] has made them a strong contender to replace petroleum based paraffin PCM. This study presents a novel attempt to analyze the solar to thermal energy storage and conversion performance of clean and sustainable PCM called Beeswax. The potential of Beeswax as TES PCM was not evaluated in detail in previous literatures. Also, there is no study available which have analyzed the solar to thermal energy conversion performance of Beeswax. Additionally, in this study chemical and physical stability of Beeswax as Shape Stabilized Composite PCM (SSCPCM) was also investigated.

In this study an eco-friendly and novel Shape Stabilized Composite PCM (SSCPCM) was prepared using naturally produced beeswax and naturally occurring Bentonite clay. SSPCM was loaded with graphite at varying wt% to prepare SSCPCM and to investigate its effect on thermo-physical characteristics. Solar to thermal energy conversion performance of the SSCPCM was also investigated.

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Access through Manipal University Jaipur

Section snippets

Material

Raw Beeswax (BW) was purchased from Madhumakhi Wala located in district Barabanki, India. It has a melting temperature range of 58 °C to 62 °C, density of 950–961 kg/m^3, and have sufficient high latent heat storage capacity as provided by the manufacturer. Bentonite clay was purchased from Sigma-Aldrich in powder form having chemical formula $H_2Al_2O_6Si$. Graphite powder with average particle size of 44 μm and purity of ≥99% was purchased from Aakar Carbons Private Limited, India. Specification …

Preparation of shape stabilized PCM (SSPCM)

PCM suffers with a major drawback of leakage during phase transition. Therefore, maintaining structural stability during charging and discharging of PCM is important for efficient storage and release of thermal energy. To reduce the chances of leakage of the PCM Shape Stabilized PCM (SSPCM) were prepared. SSPCM was prepared using raw Bentonite clay. Bentonite clay was placed in the furnace at 150 °C for 3 h to remove water molecules and other unwanted impurities. After 3 h, bentonite clay was …

Characterization

TES parameters such as enthalpy of melting, enthalpy of freezing, melting point, and freezing point are measured using Differential Scanning Calorimetry (DSC). Thermal decomposition of SSCPCM-0, SSCPCM-1, SSCPCM-3, SSCPCM-5, SSCPCM-7, and SSCPCM-9 was measured through Thermogravimetric analysis (TGA). Both DSC and TGA was done using Simultaneous Thermal Analyzer (STA-8000) of Perkin Elmer. STA performs both TGA and DSC analysis in different modes ranging from room temperature to 1600 °C. …

Thermal energy storage characteristics

Thermal energy storage parameters such as melting point, freezing point, melting enthalpy, and freezing enthalpy are the most important characteristic of any PCM to be to be used as TES material. These characteristics can be investigated through DSC. The DSC curve of pure beeswax and SSCPCM-0, SSCPCM-1, SSCPCM-3, SSCPCM-5, SSCPCM-7, and SSCPCM-9 are shown in Fig. 3(a) and (b) respectively. The heat storage capacity consist of sensible part and latent part. The sensible heating occurs in solid …

Conclusion

This study investigates the capabilities of Beeswax as potential alternative of paraffin wax for TES as SSCPCM. Various samples of SSCPCM were prepared using Bentonite as supporting material, Beeswax as PCM, and Graphite as additive. Maximum 40wt% of Beeswax was loaded in Bentonite without any leakage during phase transformation. Pure Beeswax shows excellent TES capacity of 206.63J/g (melting) and 203.35J/g (freezing) at melting and freezing temperature of 61.60°C and 54.98°C. Also, about …

Author statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We understand that the Corresponding Author is the sole contact …

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The author/authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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RESEARCH ARTICLE

Geophysical and geostatistical assessment of groundwater and soil quality using GIS, VES, and PCA techniques in the Jaipur region of Western India

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Abstract

In present study, geophysical and geostatistical variability of ground water and agricultural soil investigated in the Jaipur region of Rajasthan (Western India) by applying the geographic information system (GIS), vertical electrical sounding (VES) ,and statistical analysis. Ground water and soil samples collected from different sites from the selected study area and variation pattern of quality parameters were assessed. A contour map analysis of distribution of metals and other contaminants in the samples was conducted using GIS. Maximum concentration of metals recorded in the soil samples in order of Fe, 11.25 mg kg^{-1} > Mn, 8.6 mg kg^{-1} > Zn, 7.2 mg kg^{-1} > Cu, 0.455 mg kg^{-1}; however, maximum concentration of metals in the ground water samples was found as Zn, 2.64 mg L^{-1} > Cu, 0.86 mg L^{-1} > Fe, 0.39 mg L^{-1} > Mn, 0.18 mg L^{-1} > Pb, 0.065 mg L^{-1} > Ni, 0.016 mg L^{-1}. Observed data emphasis variability in groundwater and soil quality parameter by PCA technique indicated 84.60% and 66.98% of variance, respectively. Soil quality index (SQI) value was observed as 0.482 indicating that 46% of soil sampling sites deteriorated and shown poor quality. Similarly, water quality index (WQI) value indicates good water quality at the sampling sites TW1, TW8, TW10, and TW12; however, TW3, TW4, TW6, TW19, TW20, and TW22 sites showed very poor water quality. The present study concludes that overexploitation of groundwater and unregulated discharge of wastewater leads to depletion of water and soil quality. Further, applying geographical and geostatistical techniques in assessing water and soil quality could be more effective tools in environmental monitoring and management for environmental and health safety.

Keywords Bioaccumulation · Bioavailability · Biotransformation · Contamination · Groundwater · Metals · Principal component analysis (PCA) · Water quality

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Introduction

Rapid urbanization leads to several environmental issues, including poor living conditions, changes in land use pattern, overexploitation of water and soil, transportation congestion, resettlement, disasters, and environmental pollution (Kalayci Onac et al. 2021; Aksoy et al. 2022; Tay and Ocansey 2022; Dogan et al. 2023). Fresh water including ground water is one of the most important components of the environment and essential for human survival and wellbeing (Gavrilescu 2021). However, extensive exploitation of water by human being leads to substantial environmental cost due to contamination, scarcity, and depletion of water resources affecting water supply and health safety (Tzanakakis et al. 2020; Singh et al. 2022). Scarcity of safe drinking water is now becoming a problem due to

extensive urbanisation, industrialization, agriculture, and climate change affecting about 40% of human population globally (Calzadilla et al. 2011; Bilge Ozturk et al. 2022). Groundwater found underground in cracks and crannies in rock, sand, and soil is the main source of drinking water supply. Exploitation of groundwater may result in dissolution of numerous contaminants as it passes through the rocks and soil during leaching and percolation (Saleem et al. 2018). Trace metals emanating from different industrial, transportation, construction, and agricultural activities affect soil and water quality as recalcitrant and toxic contaminants (Romic and Romic 2003; Cetin et al. 2022a; Sahin et al., 2022). Link between soil quality and socioeconomic well-being of humans, particularly, global food security and human health have been reported (Yu et al. 2018; Kopittke et al. 2019). Soil and water contamination occurs due to various anthropogenic activities and geological processes releasing metals and other elements; therefore, assessment of soil and water quality is becoming more crucial in adapting appropriate strategies to prevent and preserve the land and water resources for human wellbeing (Ahmet et al. 2006; Cesur et al. 2021). More common metal contaminants in soil and water are Pb, Cr, As, Zn, V, Cd, Cu, and Sn reported with high levels of toxicity for biota (Yang et al. 2016; Hanfi et al. 2020; Cetin et al. 2022b).

India is one of the emerging nations with more industrial and other developmental activities having wastewater generation and discharge on the land and in the aquatic ecosystems leads to soil and water contamination (Tiwari et al. 2011). Metals persist in the soil and water, accumulates in the plants by roots uptake, and biomagnifies in the animals through food chain, which causes detrimental impact to the biota (Luo et al. 2012; Ali et al. 2019; Cetin and Abo Aisha 2023). Certain metals easily enter the food chain due to their bioavailability in the rhizosphere, uptake, and accumulation in the plants and can reach to other animals and humans through food (Gu et al. 2016; Rajendran et al. 2022). It has been reported that excessive accumulation of trace elements like cadmium, lead, and nickel in the plants causes toxicity and slows down the growth and productivity (Pandey and Sharma 2002; Zouboulis et al. 2004). A substantial threat to aquatic and terrestrial biodiversity as well as health hazards for humans posed by contaminated water and soil (Olayinka-Olagunju et al. 2021). Types of rock, physicochemical characteristics of soil, atmospheric precipitation, and surface geochemical processes affect the groundwater quality parameters and contamination (Garg and Hassan 2007; Cesur et al. 2021). Groundwater is most reliable source even in India because it provides a significant proportion of the country's drinking and agricultural water requirements (Mahmood and Kundu 2005).

Physico-chemical characteristics of soil also affects the water quality of groundwater at a given regions (Griffiths et al. 2010; Hermans et al. 2020). Different physio-chemical and biological indicators have been used in various studies to evaluate the soil quality (Filip 2002; Schloter et al. 2003). GIS has evolved into a trustworthy instrument for absorbing, analyzing, and displaying spatial data that can be utilized for environmental monitoring, planning, and resource management applications (Cetin 2015; Singha et al. 2015). The geographical information system (GIS) has become an important tool in research for resource management as it allows users to use geographical data in a variety of context and way in an integrated approach. Remote sensing (RS) and GIS studies in integration make it easier to work in relatively broad areas, particularly in environmental impact assessment for sustainable urban planning and resource utilization (Cetin 2019; Pekkan et al. 2021; Cetin et al. 2022c). Convergence of data concerning environmental assessment-related issues as well as the manipulation of spatial data into various forms in response to geosocial requirements may be accomplished using GIS (Cetin et al. 2022d). The principal component analysis (PCA) is a prominent statistical analysis tool for investigating data patterns thorough factor analysis approach. Basic purpose of PCA is to create new variables as principal components, from a set of existing original variables (Wu et al. 2020). Potential of geophysical information system-based geostatistical methodologies in assessing the region's groundwater and soil quality as well as its susceptibility to water-borne diseases reported (Ali and Ahmad 2020).

The Sanganer, Jaipur region of Rajasthan, Western India, having more industrial activities specially printing and dyeing operations leads to huge amount of wastewater generation and discharge in water and agricultural soil through unregulated disposal and irrigation practices. Very limited data are available related to using geographical information system and geostatistical techniques in the ground water and soil quality assessment. Therefore, the present study was conducted to assess ground water and soil quality at different sites based on a minimal set of interconnected geophysical and chemical criteria at Sanganer, Jaipur region of Rajasthan, Western India, and apply geophysical and geostatistical including GIS, VES, and PCA techniques to emphasize the water and soil quality parameters for environmental monitoring and assessment.

Materials and methods

Study area

The whole study conducted in the industrial and agricultural tracts in the north of Jaipur–Sanganer regions at different selected sampling sites, situated between 26° 49° and 26° 51° N and 75° 46° and 75° 51° E in the Jaipur district,

Rajasthan, Western India (Fig. 1). One selected study site, the Sanganer, is famous for its hand-printed textiles have land size of 78.24 square kilometres, situated on NH-12, 10 kilometres to the southwest of Jaipur City. The Sanganer is well-known for its distinctive type of printing "Sanganer Printing" basically in the small-scale industries of the Chippas community, involving dyeing and printing of textiles (Dadhich et al. 2016). Dyeing and printing processes release wastewater during water-based color fixing procedure and discharged in the surrounding areas which pollutes water and soil. The chippas community either transport the textiles to a well dug on the bank of the Dravyawati River or

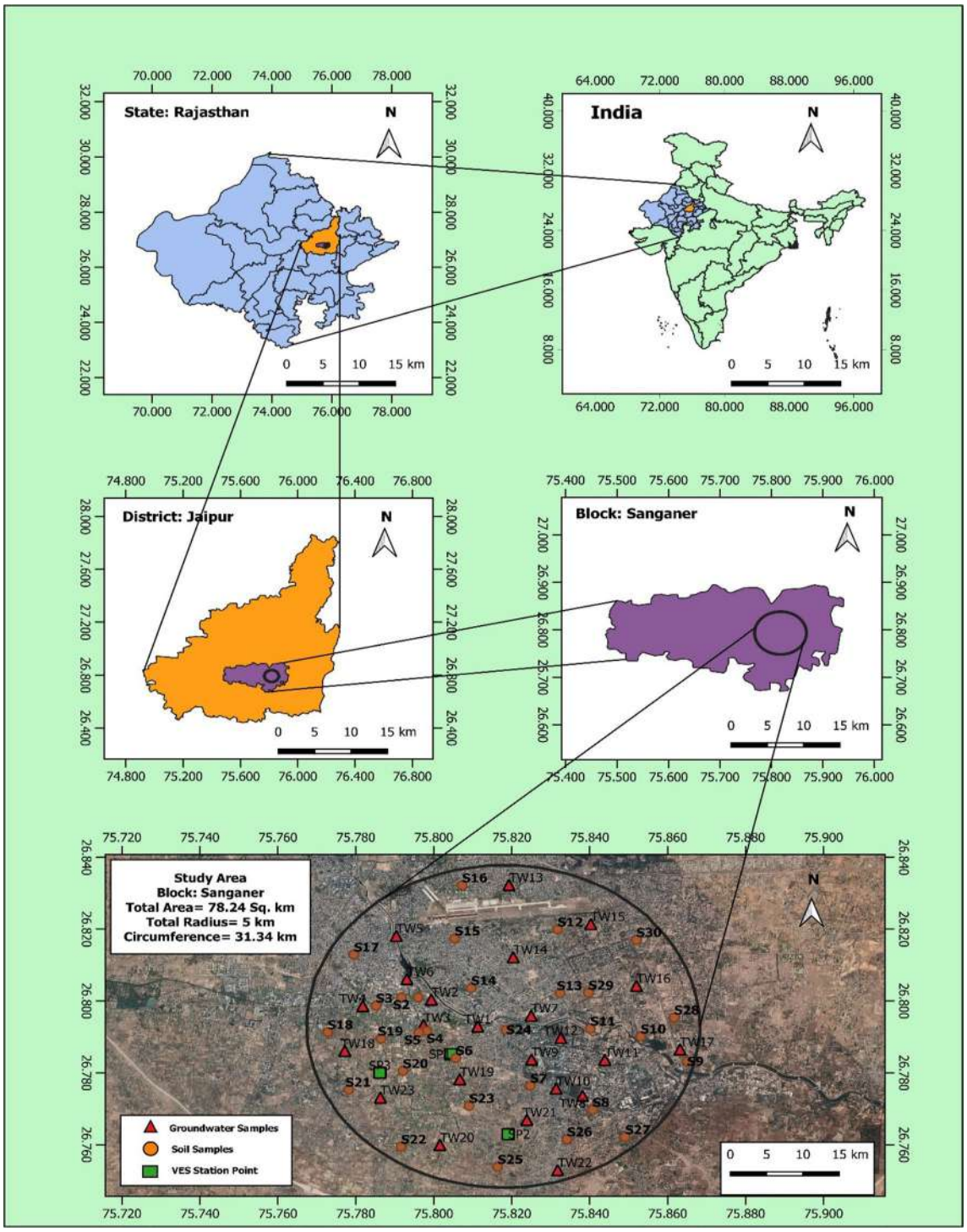


Fig. 1 Sampling sites of soil and ground water selected in the study area, Sanganer, Jaipur, Rajasthan, India

wash it at their wells in the city at various places randomly. Textile wastewater along with sewage from across the of Jaipur city discharged directly into the Dravyawati river in the selected study area is being polluted. Historically, Sanganer was primarily an agricultural region; however, during the last decade, the textile and dying industries have dramatically risen in the area and encroached the previously untapped agricultural land. With more than 250 separate printing units connected, it has emerged as one of the major centers of the printing and dying industries nowadays today in India. Growing demand and low production costs leads to the introduction of synthetic and chemical dyes, which have several environmental impacts. The regions of Jaipur–Sanganer with a high number of dyeing and printing industrial units releasing tonnes of waste into the aquatic environment, agricultural fields, and on open spaces nearby, polluting the water and soil (Sharma et al. 2014). Contamination of water and soil have negative impact on nutrition and human health due to deterioration of drinking water quality and food quality; however, at severe stage, poor quality may prevent soil from performing its natural physio-chemical and biological functions and deteriorate region's overall productivity of the terrestrial ecosystem.

Sampling sites and sampling

One-liter capacity plastic bottle rinsed with distilled water used to collect the groundwater samples. Grab sampling conducted for groundwater water sampling and samples preserved in the bottles with adjusted pH 2 and stored in refrigerator at 4 °C with slightly acidified with nitric acid (HNO_3) for analysis of water quality parameters including metals (Mn, Cu, Ni, Zn, Pb, and Cu). In Sanganer industrial region, having a new industrial area (RICCO) and an industrial zone (RSMDC), a quantitative soil and water sampling conducted to evaluate the water and soil quality parameters of the agricultural land as well as the degree of contamination in water due to industrial activities. Soil samples (250 g) taken from 30 randomly selected sites with a depth of 45 to 60 cm within a 5-kilometer radius of the Sanganer industrial zone and packed in fresh plastic zip-lock bag separately to determine the soil quality parameters (Fig. 2). All the sampling sites were precisely geotagged and labeled from S1 to S30 using a Garmin GPS device (model 68 s), allowing for the retrieval of a variety of location-specific data (Luo et al. 2011). Description of location and sampling sites are shown in the Table 1. The geoelectrical resistivity approach used to conduct field surveys in the study region which requires injecting a man-made current through several electrodes (AB) into the subsurface medium and observing the voltage changes at the potential electrodes (MN) to assess the variation in the ground's resistivity (Binley et al. 2015).

Analysis of soil and water quality parameters

Collected soil samples analyzed for 10 functional indicators parameters (i.e., pH, EC, OC, P, S, K, Zn, Fe, Cu, and Mn) for soil quality (YanBing et al. 2009). Similarly, collected water samples from different selected sites analyzed for water quality parameters in the laboratory. Average of all sets of triplicates calculated and values recorded into the data system (Juhos et al. 2019). All the analysis conducted following the procedure established by the American Public Health Association (Baird and Bridgewater 2017). A typical laboratory digital micro-processor pH meter used to estimate hydrogen ion concentration (pH) in the water samples (Salem et al. 2020). Similarly, electrical conductivity (EC) determined using an electrical conductivity meter (an EC probe and equipment that had been calibrated) by following the procedure of McNeill 1992. A digital water quality test kit used to evaluate total dissolved solids (TDS); however, EDTA titration method was used to calculate total hardness in the water samples. An argentometric titration used to quantify the amount of chloride in a water sample followed by alkalinity determined using the titrimetric method. UV-visible spectrophotometer used to determine the amount of fluoride in the collected water samples. Titration method used to estimate soil organic carbon (SOC) in the soil samples (Walkley and Black 1934) which involves oxidizing organic material in sulfuric acid with a predetermined quantity of chromate (Sato et al. 2014; Gelman et al. 2012). The Johnson–Nishita procedure used to measure sulfur content in the soil samples (Dean 1966). Sulfur and other minerals present in soil solution specially SO_4 ions adsorbed are the principal source of sulfur in soil. The replacement of SO_4 ions is of the utmost importance, and phosphate ions substituted wherever possible for adsorption and monocalcium phosphate, or phosphate ions, are present in the soil. The SO_4 ions are replaced with $CaCl_2$ ions in a more effective way throughout the extraction process and SO_4 extract turbulence determined by using a spectrophotometer. Potash content in soil samples estimated using a flame photometer following the procedure of Brondi et al. (2016).

Metal estimation

The concentration of Fe, Cu, Zn, Ni, Mn, and Pb in groundwater samples, whereas the metal Fe, Zn, Cu, and Mn analyzed in the soil samples estimated after complete digestion in $HClO_4$ and HNO_3 (3 : 1), using hollow cathode lamp at a certain wavelength into an atomic absorption spectrophotometer (AAS, Shimadzu) in comparison to standard metal solutions.

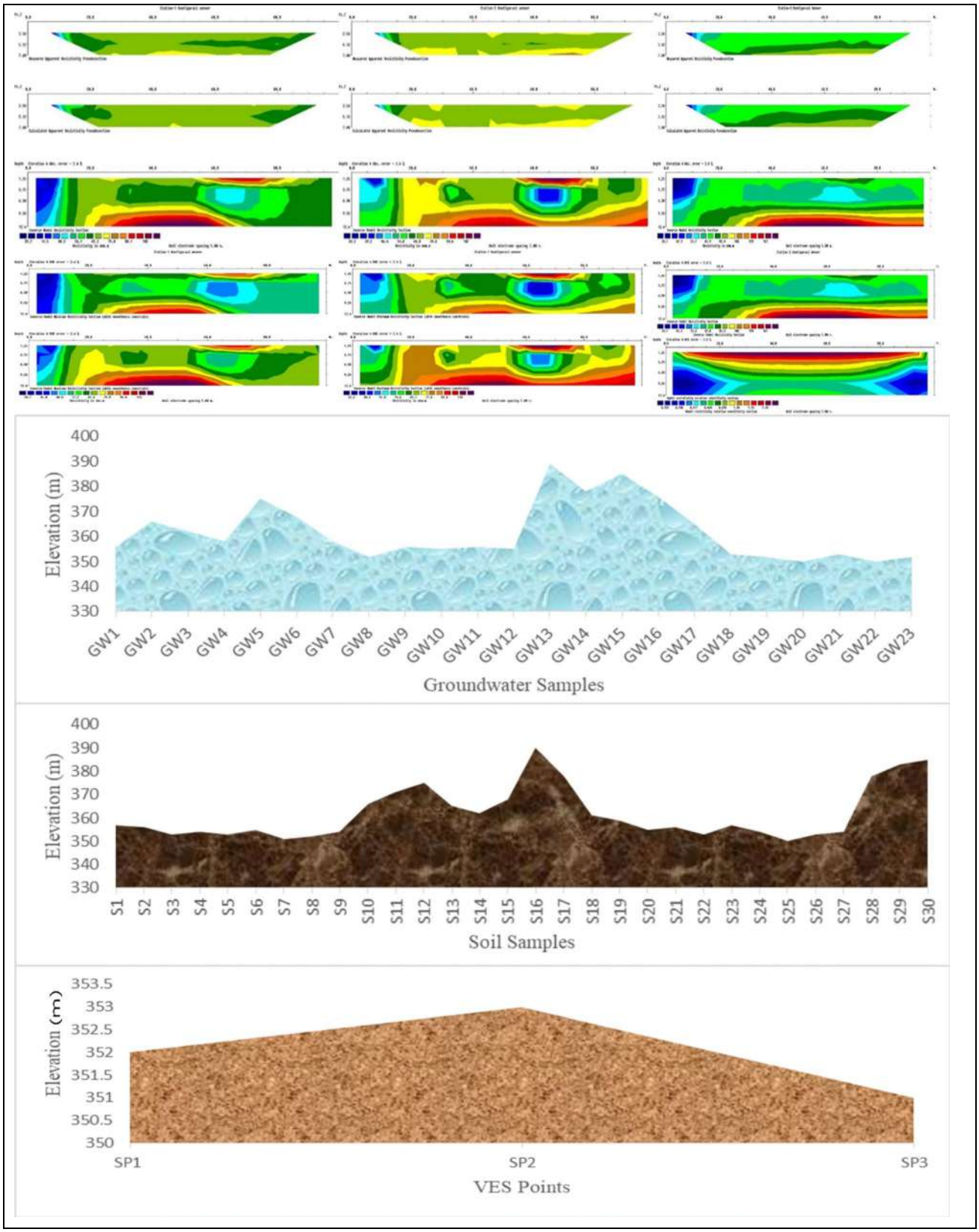


Fig. 2 Geoelectrical layers and elevation point of different sampling sites at the study area, Sanganer, Jaipur, Rajasthan, India

Table 1. Description of sampling sites of ground water samples, soil samples and VES station selected at Sanganer study area, Jaipur (Rajasthan), India

Ground water sample			Soil samples		
Sampling site	Latitudinal and longitudinal position	Elevation (m)	Sampling site	Latitudinal and longitudinal position	Elevation (m)
GW1	26.7929 N, 75.8113 E	357	S1	26.8010 N, 75.7960 E	354
GW2	26.8004 N, 75.7994 E	356	S2	26.8010 N, 75.7917 E	350
GW3	26.7933 N, 75.7974 E	353	S3	26.7987 N, 75.7852 E	353
GW4	26.7986 N, 75.7818 E	354	S4	26.7916 N, 75.7982 E	354
GW5	26.8181 N, 75.7904 E	353	S5	26.7912 N, 75.7962 E	378
GW6	26.8061 N, 75.7931 E	355	S6	26.7841 N, 75.8057 E	383
GW7	26.7959 N, 75.8250 E	351	S7	26.7764 N, 75.8248 E	385
GW8	26.7736 N, 75.8382 E	352	S8	26.7697 N, 75.8408 E	356
GW9	26.7837 N, 75.8251 E	354	S9	26.7832 N, 75.8650 E	366
GW10	26.7756 N, 75.8314 E	366	S10	26.7901 N, 75.8531 E	362
GW11	26.7836 N, 75.8439 E	371	S11	26.7923 N, 75.8402 E	358
GW12	26.7897 N, 75.8326 E	375	S12	26.8199 N, 75.8318 E	375
GW13	26.8323 N, 75.8193 E	365	S13	26.8022 N, 75.8324 E	368
GW14	26.8122 N, 75.8204 E	362	S14	26.8036 N, 75.8096 E	358
GW15	26.8214 N, 75.8403 E	368	S15	26.8174 N, 75.8054 E	352
GW16	26.8042 N, 75.8520 E	390	S16	26.8322 N, 75.8073 E	356
GW17	26.7865 N, 75.8632 E	378	S17	26.8129 N, 75.7795 E	355
GW18	26.7861 N, 75.7772 E	361	S18	26.7913 N, 75.7728 E	356
GW19	26.7782 N, 75.8067 E	359	S19	26.7895 N, 75.7865 E	355
GW20	26.7599 N, 75.8016 E	355	S20	26.7805 N, 75.7921 E	389
GW21	26.7669 N, 75.8239 E	356	S21	26.7753 N, 75.7782 E	378
GW22	26.7529 N, 75.8318 E	353	S22	26.7594 N, 75.7916 E	385
GW23	26.7731 N, 75.7863 E	357	S23	26.7708 N, 75.8091 E	376
			S24	26.7920 N, 75.8186 E	365
	VES		S25	26.7538 N, 75.8164 E	353
SP1 (VES)	26.7852 N, 75.8044 E	352	S26	26.7615 N, 75.8342 E	352
SP2 (VES)	26.7629 N, 75.8191 E	353	S27	26.7621 N, 75.8491 E	350
SP3 (VES)	26.7800 N, 75.7862 E	351	S28	26.7954 N, 75.8617 E	353
			S29	26.8023 N, 75.8397 E	350
			S30	26.8170 N, 75.8520 E	352

Geostatistical analysis

To assess overall quality of water and soil samples collected from the different sites in the study area, data of soil and water quality parameters analysed thoroughly by applying geostatistical tools. Quantitative evaluation's framework combines geotechnical and physicochemical analysis of water and soil samples with descriptive statistics and statistical modelling. Outcome data is gathered after the laboratory chemical analysis of selected soil and water samples, followed by review with analysis of data on SPSS software (version 22 for Windows). Discriminating analysis (correlation) of data performed using Statistical Package for the Social Sciences (SPSS) for Windows, version 23.0. (Ukah et al. 2019, 2020). Several statistical methods used in data analysis and models including MV, SD, and CV (Li et al. 2016; Zhu et al. 2019). Further, water quality index (WQI) and soil quality index (SQI) evaluated to assess the region's overall variations and patterns of water and soil quality parameters using site-specific indicator evaluation outputs. Weighted arithmetic mean technique for WQI was used in this investigation (Tyagi et al. 2013).

$$WQI_A = \sum_{i=1}^{n} qi\ X\ Wi,$$

$$\sum_{i=1}^{n} Wi = 1,$$

where Wi is the unit weight of each parameter, qi is the 0–100 subindex rating for each variable, and n is the number

of subindices aggregated. Multivariate statistical technique, the principal component analysis (PCA), was used to reduce the dataset into new variables, create a minimum data set (MDS), and analyze relationships between different metal contents in the water and soil samples and other quality parameters including pH, TOC, and EC along with factor analysis (FA) to identify specific factor weight of a particular metal (Weissmannová and Pavlovský 2017). The SAS Systems for Windows 10 platform and Statistica 12.5® software used to perform principal component analysis (PCA), followed by a Varimax rotation used to rotate each PCA component. The Varimax rotation method of factor analysis and the principal component primary result analysis performed by following the procedure of Kaiser 1958 and Maiz et al. 2000. For the GIS-based evaluation, SQI and WQI maps, spatial distribution maps, area maps, and thematic maps for the region produced by using Sentinel 2 Satellite data (March 2021) in bands: 3, 4, 8 developed on ArcGIS software 10.8 (2020).

Results

Groundwater samples (23) and soil samples (30) collected from selected sampling sites of the study area, Jaipur regions of Rajasthan, Western India, analyzed for quality parameters. Based on the sounding data, the present study inferred with three geoelectrical layers comprising topsoil, unsaturated, and saturated zones (Fig. 2). For all the sections topmost layer assumed to be topsoil, above the water table and substantially drier more often reflects greater resistivity. Peat investigated in the topsoil layer by resistance correlation with soil lithology from neighboring boreholes. Regional lithology of Sanganer shown in the Table 2 which indicates formation depth range as alluvium, 0.0–95 m; weathered, 0.69–128 m; and hard rock, 9.2 m. In present study, the third layer of all the sections represent highest concentration of geoelectrical sections with low resistivities (less than 10 m). Values and their variation pattern of water quality parameters in 23 groundwater samples at different sites of the study area depicted in Fig. 3. Maximum values of different parameters of groundwater samples recorded as pH, 8.0; electrical conductivity (EC), 3.01 S/m, TDS, 1501 mg/l; fluoride, 1.9 mg/l; total hardness, 273 mg/l; Ca, 88.1 mg/l; Mg, 12.67 mg/l; chloride, 227.42 mg/l; HCO_3, 61.87 mg/l; and CO_3, 58.29 mg/l. However, maximum metal concentration in groundwater samples recorded as Zn, 2.64 mg/l; Cu, 0.862 mg/l; Fe, 0.392 mg/l; Mn, 0.181 mg/l, Pb, 0.065 mg/l; and Ni, 0.016 mg\l. pH and TDS level in the ground water samples found in the range of 7.0 to 8.0 and 559 to 1501 mg/l, indicate that values are within the range of 6.5 to 8.5 and 500 to 1500 mg/l, respectively, as per WHO standard of water quality. Similarly, for 30 soil samples, maximum values of soil quality parameters recorded as pH, 8.4; electrical conductivity (EC), 0.27 µS/m; organic carbon, 0.23 %; phosphorous, 50.23 mg/kg; potash, 786 mg/kg; sulfur, 29.68 mg/kg. However, maximum metal concentration in the soil samples recorded as Fe, 11.25 mg/kg; Mn, 8.65 mg/kg; Zn, 7.26 mg/kg; and Cu, 0.45 mg/kg as shown in Fig. 4. Result shows that none of the parameters including pH have a strong correlation. Samples' scores and loadings plots together showed physio-chemical characteristics of soil that affect each order on the score plots. Retained variables divided into groups using the factor analysis technique in accordance with statistical factors and correlation matrix (Table 3). As depicted in the Table 4, maximum WQI found in groundwater sample collected at sampling site TW22 and minimum in the sample collected from TW12. Results of PCA and FA analysis for groundwater revealed that the first component (PC1), which accounted for 39.12% of the total variance, included Mn, pH, and EC; however, S, OC, and P made the second component (PC2) with a total variance of 12.54%. Similarly, pH, Mn,

Table 2. Regional lithology of the study area, Sanganer, Jaipur (Rajasthan), India

Aquifers depth (m)	Aquifers	Geological formation	Depth (m)	Laboratory experiment model
0–95	Alluvium	Surface soil, sandy clay	0–4	
		Clayey sand	4–13	
		Clayey kankar	13–19	
0.6–128	Weathered	Sandy clay with kankar	19–29	
		Kankar and clay	29–38	
		Kankar and sand	38–47	
9.2	Hardrock	Weathered schist	47–73	
		Schist	73–150	

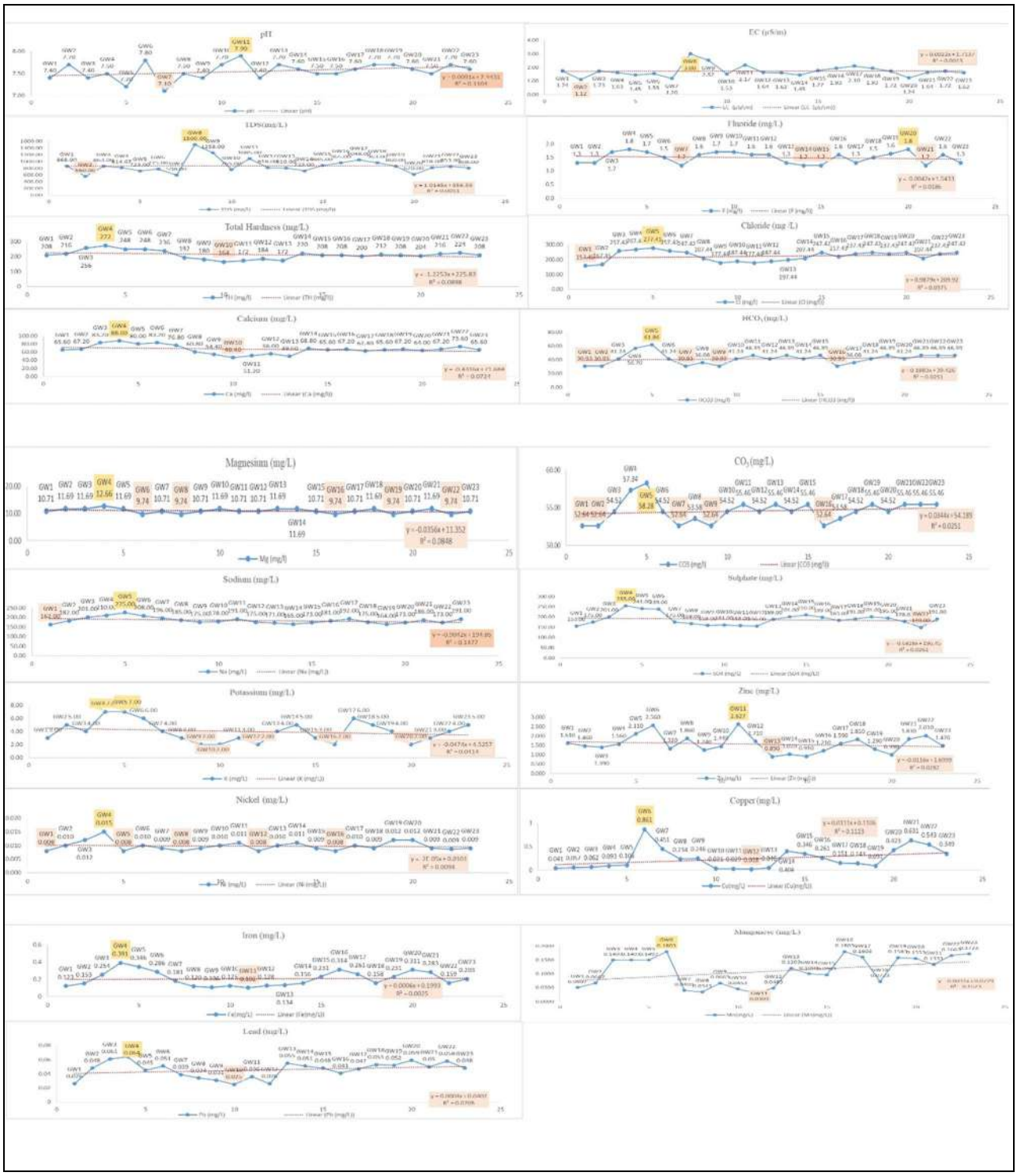


Fig. 3 Variations in water quality parameters of ground water samples collected from in different sites at the study area, Sanganer, Jaipur, Rajasthan, India

and Cu made PC3 with a total variance of 11.42% followed by phosphorous made PC4 a total variance of 9.06%, while all four extraction factors accounted for 72.15% of the overall variation. However, in case for soil samples Mn, pH, and EC produced the first component (PC1) with 24.26% of the variance followed by the second component (PC2) produced included S, OC, and P with a total variation of 17.48%, while PC3 made up of pH, Cu, and Mn with a total variance of

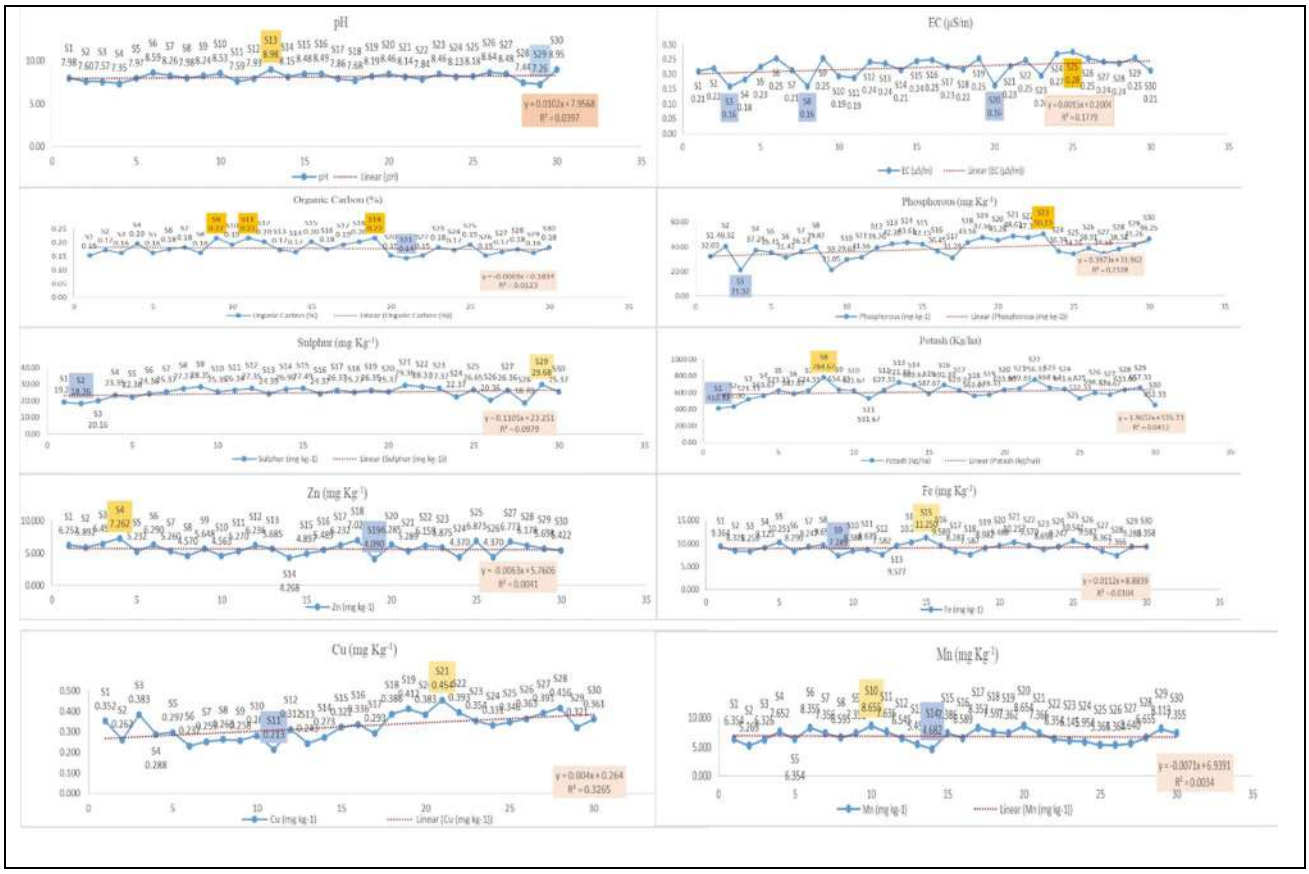


Fig. 4 Variations in soil quality parameters of soil samples collected from different sites at the study area, Sanganer, Jaipur, Rajasthan, India

13.65% and PC4 contained phosphorus with a total variance of 11.58% (Fig. 5A). Result shows that water quality of groundwater samples collected at TW1, TW8, TW10, and TW12 sampling sites in the Sanganer area are in very good quality category; however, groundwater samples from TW3, TW4, TW6, TW19, and TW22 sites recorded under very poor water quality category with high level of contaminants (Fig. 5B). Similarly, total 9 soil quality parameters including pH, EC, OC, P, S, K, Zn, Fe, and Mn used to evaluate the soil quality index (SQI), and an average soil quality index (SQI) value 0.517 recorded for the selected study area based on MDS, with a range of 0.341 to 0.635 (Fig. 5B). According to the suggested framework, the SQI values for the entire selected region divided into three categories viz; category 1 (C1), SQI value less than 0.4 (degraded); category 2 (C2), SQI value between 0.41 and 0.5 (moderately degraded); and category 3 (C3), SQI value greater than 0.51(least degraded). SQI revealed that soil samples at S19 site showed highest SQI score, 0.636, followed by S6, S7, S12, S13, S15, S16, S17, S18, S20, S21, S22, S23, S25, S27, S29, and S30 more than average as shown in Fig. 5B. Data shows that 13.3% of the soil samples from the study area have low soil pollution with good soil health; however, 40% of the soil samples have moderate contamination with SQI values in the range of 0.41 to 0.5 and 46.6% of soil samples shown as degraded soil under the poor-quality category with SQI values more than 0.51. At 5 kilometers away from the Sanganer industrial regions, high-intensity farming techniques, and conventional farming practices, excessive fertilizer use may be responsible for the soil degradation in the selected sites. Based on SQI score, the S19 site showed highly contaminated soil in the study area; however, it is crucial to note that the high score may be due to increased chemical build-up and other components like sulfur rather than trace metals having low concentration; however, it may be useful in environmental health assessment. Results of the factor analysis (FA) recorded insufficient if the Kaiser–Meyer–Olkin (KMO) test result value found to be less than 0.5; however, KMO found less FA findings in the test's outcome than the chemical examination of soil samples. FA did not alter KMO testing significantly because there is no related cut-off point, and the results for the sample given a less clear indication of the applicability of the FA as KMO values estimated 0.487 and 0.466 (less than 0.5) for the groundwater and soil samples, respectively. Percentage (%) of variance evaluated by placing three components out of

Table 3. Correlation matrix[a] of ground water and soil samples collected from different sites at Sanganer study area, Jaipur, Rajasthan, India

Groundwater quality parameters

		pH	EC	TDS	F	TH	Ca	Mg	Cl	HCO_3	CO_3	Na	K	SO_4	Zn	Ni	Mn	Cu	Fe	Pb
Correlation	pH	1.000	.080	.082	.047	− .348	− .338	− .–	− .207	.078	.078	− .284	.008	− .087	.250	.300	.121	.047	− .213	.219
	EC	.080	1.000	1.000	.217	− .366	− .327	− .371	− .211	− .185	− .185	− .088	− .251	− .282	.214	− .241	− − .241	− .147	− .309	− .326
	TDS	.082	1.000	1.000	.217	− .367	− .328	− .370	− .212	− .185	− .185	− .088	− .252	− .279	.212	− .239	− .242	− .149	− .308	− .326
	F	.047	.217	.217	1.000	.068	.074	− .040	.194	.267	.267	.257	− .111	.155	.213	.337	.131	− .259	.240	.036
	TH	− .348	− .366	− .367	.068	1.000	.993	.217	.695	.320	.320	.605	.671	.698	.153	.351	.491	.322	.693	.599
	Ca	− .338	− .327	− .328	.074	.993	1.000	.096	.705	.282	.281	.586	.641	.676	.180	.307	.517	.374	.687	.580
	Mg	− .132	− .371	− .370	− .040	.217	.096	1.000	.028	.361	.361	.241	.346	.280	− .190	.399	− .131	− .366	.156	.244
	Cl	− .207	− .211	− − .212	.194	.695	.705	.028	1.000	.538	.538	.572	.569	.734	.044	.295	.645	.345	.735	.659
	HCO_3	.078	− .185	− .185	.267	.320	.282	.361	.538	1.000	1.000	.441	.480	.560	.242	.343	.381	− .032	.462	.449
	CO_3	.078	− .185	− .185	.267	.320	.281	.361	.538	1.000	1.000	.441	.480	.560	.242	.343	.381	− .032	.462	.449
	Na	− .284	− .088	− .088	.257	.605	.586	.241	.572	.441	.441	1.000	.615	.590	.498	.154	.288	.115	.582	.215
	K	.008	− .251	− .252	− .111	.671	.641	.346	.569	.480	.480	.615	1.000	.672	.284	.314	.411	.074	.459	.529
	SO_4	− .087	− .282	− .279	.155	.698	.676	.280	.734	.560	.560	.590	.672	1.000	− .010	.451	.589	.185	.811	.590
	Zn	.250	.214	.212	.213	.153	.180	− .190	.044	.242	.242	.498	.284	− .010	1.000	− .145	− .054	.175	− .008	− .143
	Ni	.300	− .241	− .239	.337	.351	.307	.399	.295	.343	.343	.154	.314	.451	− .145	1.000	.281	− .117	.388	.604
	Mn	.121	− .241	− .242	.131	.491	.517	− .131	.645	.381	.381	.288	.411	.589	− .054	.281	1.000	.393	.750	.695
	Cu	.047	− .147	− .149	− .259	.322	.374	− .366	.345	− .032	− .032	.115	.074	.185	.175	− .117	.393	1.000	.270	.288
	Fe	− .213	− .309	− .308	.240	.693	.687	.156	.735	.462	.462	.582	.459	.811	− .008	.388	.750	.270	1.000	.582
	Pb	.219	− .326	− .326	.036	.599	.580	.244	.659	.449	.449	.215	.529	.590	− .143	.604	.695	.288	.582	1.000

Soil quality parameter

		pH	EC	OC	Phosphorus	Sulfur	Potash	Zn	Fe	Cu	Mn
Correlation	pH	1.000	.163	− .071	.166	.148	.111	− .324	.291	− .039	− .089
	EC	.163	1.000	.125	.059	.113	.075	− .064	.079	.131	− .264
	OC	− .071	.125	1.000	− .237	.226	− .174	.023	− .382	− .331	.288
	Phosphorus	.166	.059	− .237	1.000	.290	.250	− .178	.385	.400	− .109
	Sulfur	.148	.113	.226	.290	1.000	.493	− .101	.202	− .026	.314
	Potash	.111	.075	− .174	.250	.493	1.000	− .291	.160	− .064	− .012
	Zn	− .324	− .064	.023	− .178	− .101	− .291	1.000	− .362	.149	.110
	Fe	.291	.079	− .382	.385	.202	.160	− .362	1.000	.054	− .234
	Cu	− .039	.131	− .331	.400	− .026	− .064	.149	.054	1.000	− .059
	Mn	− .089	− .264	.288	− .109	.314	− .012	.110	− .234	− .059	1.000

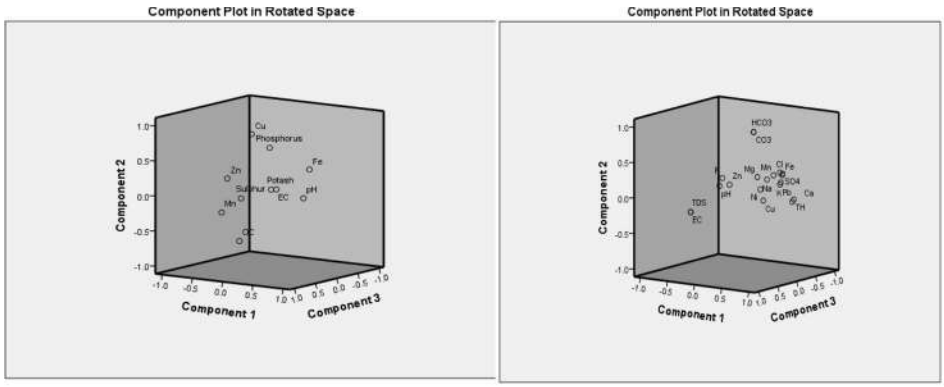
Table 4. Water quality and soil quality Index

Groundwater quality index						
Parameters	Quantity of sample	WQI (mean)	Std. deviation	Std. error	Maximum	Minimum
pH	23	7.5522	.0035	.0020	8.0000	7.0000
EC (µS/m)	23	1.7400	.0027	.0015	3.0100	1.1100
TDS (mg/l)	23	868.7246	.7633	.4407	1501.0000	559.0000
Fluoride (mg/l)	23	1.4928	.0054	.0031	1.9000	1.1000
TH (mg/l)	23	211.1304	.5325	.3074	273.0000	163.0000
Ca (mg/l)	23	66.5043	.0035	.0020	88.1000	46.3000
Mg (mg/l)	23	10.9249	.0009	.0005	12.6700	9.7300
Cl (mg/l)	23	221.7787	.0025	.0014	277.4200	157.4400
HCO_3 (mg/l)	23	41.6862	.0041	.0024	61.8700	30.9200
CO_3 (mg/l)	23	54.6017	.0082	.0047	58.2900	52.6300
Na (mg/l)	23	184.0000	.6035	.3484	226.0000	161.0000
K (mg/l)	23	3.9565	.6745	.3894	8.0000	1.0000
SO_4 (mg/l)	23	188.2609	.8165	.4714	256.0000	148.0000
Zn (mg/l)	23	1.5612	.0083	.0048	2.6400	1.6000
Ni (mg/l)	23	0.0098	.0010	.0006	.0160	.0011
Mn (mg/l)	23	0.1099	.0004	.0002	.1810	.0300
Cu (mg/l)	23	0.2442	.0008	.0005	.8620	.0170
Fe (mg/l)	23	0.2068	.0008	.0005	.3920	.1010
Pb (mg/l)	23	0.0456	.0008	.0004	.0650	.0240
Soil quality index						
Parameters	Quantity of sample	SQI (mean)	Std. deviation	Std. error	Maximum	Minimum
pH	30	8.11	.0064	.0037	8.40	7.98
EC (µS/m)	30	.2240	.0008	.0005	.2760	.1580
Organic carbon (%)	30	.1793	.0061	.0035	.2300	.1400
Phosphorous (mg kg^{-1})	30	38.1197	.0009	.0005	50.2310	21.0500
Sulfur (mg kg^{-1})	30	24.9634	.0006	.0004	29.6810	18.3620
Potash (kg/ha)	30	607.1889	.7385	.4264	786.00	410.00
Zn (mg kg^{-1})	30	5.6635	.0010	.0006	7.2630	4.0890
Fe (mg kg^{-1})	30	9.0579	.0006	.0003	11.2510	7.2890
Cu (mg kg^{-1})	30	.3261	.0005	.0003	.4550	.2130
Mn (mg kg^{-1})	30	6.8290	.0007	.0004	8.6560	4.6810

the four PC ranges (component based on Jolliffe's criterion) and recorded 84.60% and 66.98% for groundwater and soil samples, respectively (supplementary data).

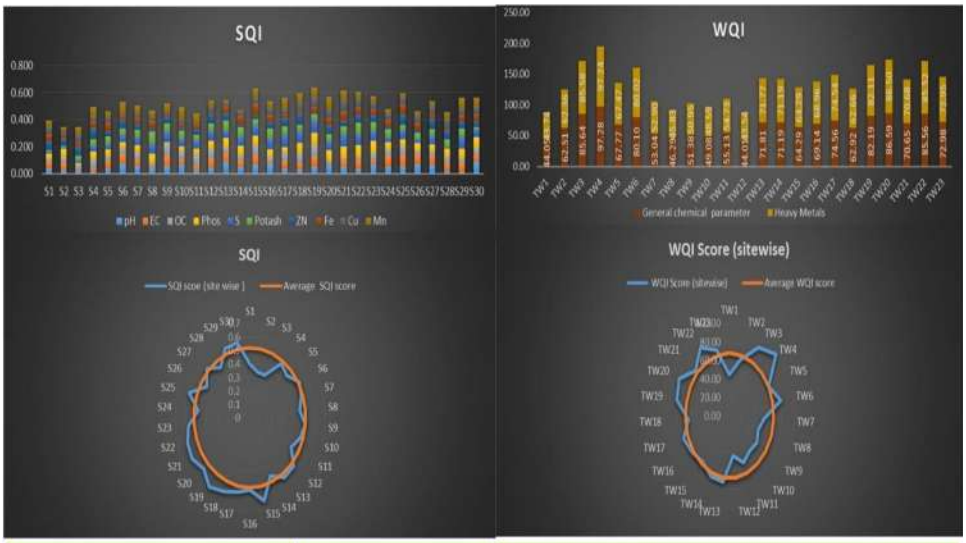
Discussion

Collected samples from the selected study area, Jaipur regions of Rajasthan, Western India, evaluated for water and soil quality parameters which indicate slightly basic in nature as pH varied within the ranged of 7.0 to 8.0 in the samples. pH is one of the essentially functional parameters for evaluating the quality of soil and water (Filip 2002). Depending on the underlying geological units' actual resistivity, the geoelectrical characteristics utilized to create earth models which displayed as subsurface stratigraphy and from which possible aquifer zones mapped for sampling and assessing the groundwater quality parameters at different sites in the selected region (Mogaji and Omobude 2017). Higher value of EC in groundwater samples indicates impurity as compared to pure water which is not an excellent conductor of electricity having a lower EC than the groundwater. According to previous studies, groundwater exhibits low resistivities between 10 and 100 Ωm in the context of sedimentary (Adagunodo et al. 2018). Kaiser's criterion replaced with Joliffe's criterion since it is too high and allows for a graphic representation of the factor loading through a dipole using the first three components (Jolliffe 1972). However, soil solutio"s EC indicates total amount of salts and ions present in the soil (Bronson et al. 2005; Peralta and Costa 2013). A significant indicator of the soil quality is electrical conductivity, which reflects the salinity of the soil



Soil samples Ground water samples

[A]



Category-A	0-25	Excellent
Category-B	26-50	Good
Category-C	51-75	Poor
Category-D	76-100	Very Poor

[B]

Fig. 5 Component plot of ground water and soil samples (**A**). Soil quality index (SQI) and water quality index (WQI) of collected samples (**B**)

(Hardie and Doyle 2012). Studies revealed that low resistivity values inside the underlying strata likely caused by high ion concentrations and fine-grained sediments like silt and clay (Amaya et al. 2018). Another soil quality parameter of soil is known as soil organic carbon (SOC) contains organic remains of dead animals and plants at various stages of decomposition which affects physicochemical characteristics of the soil (Campbell 1978). Concentration of SOC in the soil samples is one of the fundamental criteria for soil quality (Unger 1997). Agricultural production, plant development, and soil fertility also depend on phosphorus content, which is the second-most important macronutrient in soil after nitrogen (Malhotra et al. 2018). Similarly, soil fertility, pH levels, plant development, and efficient nitrogen fixation processes dependent on its existence in the soil (Jordan and Ensminger 1959). Potash content is another essential macronutrient for preserving soil fertility and pH homeostasis. Fertilizer used usually to supplement K into the soil in case of its deficiency because plants require K for their growth and development during the life cycle (Morgan and Connolly 2013). However, high concentration of potash in soil also effects soil quality and causes soil degradation (Sillanpaa 1982). Water and soil quality assessment studies have sparked interest on a global scale due to growing

attention on the depletion of water and soil quality to assess the environmental impact of anthropogenic activities for environmental sustainability (Raiesi and Kabiri 2016). Various attempts have been made to measure the quality of the soil and water using different indicators (Armenise et al. 2013; Seybold et al. 2018). Water quality index makes it possible to examine water quality in a variety of ways that affect a stream's ability to sustain by its processes and to ensure sustainable use of water resources to minimize risks and preserve aquatic ecosystems (Akkaraboyina and Raju 2012). WQI is an important distinctive grade which summarizes overall quality of water and helps in selecting the most effective treatment strategy for wastewater before its final discharge and disposal to prevent water contamination (Tyagi et al. 2013). Status and level of contamination of water has been evaluated by using water quality parameters and quality index (Shah and Joshi 2017). The WQI and SQI approach is one of the best and most widely used techniques for assessing the quality of soil and water for adapting treatment and conservation strategies (Arshad and Martin 2002; YanBing et al. 2009). Physio-chemical and biological characteristics of soil indicated by the soil quality which is crucial to its long-term functionality and productivity and sustainability. An encompassing view of the region's overall soil quality evaluated assessing the soil quality index (Bhattacharyya 2017). Similarly, minimum data set (MDS) for the data reflecting the soil's functional capacity used in evaluating the soil quality index (Klimkowicz-Pawlas et al. 2019). By using multivariate geostatistical techniques, contemporary data analysis and metal content estimation of four metals (Zn, Cu, Mn, and Fe) in the soil and six metals (Zn, Cu, Mn, Fe, Pb, and Ni) in groundwater emphasis water and soil quality (Lu et al., 2010). Metals Zn, Ni, Mn, Cu, Fe, and Pb chosen based on PCA, FA, and CA investigations as reference elements for soil and groundwater contamination. Several studies evaluated metal contamination of soil and water in the different urban and industrial regions using principal component analysis (Manta et al. 2002; Skrbic and Djurisic-Mladenovic, 2007, Guo et al., 2013). PCA technique used to show the relationship among metals concentration and other parameters (pH, EC, TOC) in the soil and water (Weissmannová and Pavlovský 2017). FA produced using a constant value for all the soil and water quality parameters with a correlation matrix to minimize the effect of varying units on the variables (Lin et al. 2002). Kaiser–Meyer–Olkin (KMO) test used to evaluate whether the sample is large enough to use factor analysis (Kaiser 1974). In principal component analysis (PCA), variables referred to as principal components (PC) used to illustrate the relation between two elements (Esbensen and Geladi 2010). In similar study, Tripathi and Singal (2019) evaluated water quality of the Ganga River using PCA technique. In contrast, Praus (2019) used primary component weighted index (PCWI) for assessing the quality of both untreated and treated wastewater to evaluate WQI. Data indicate that unregulated discharge of wastewater including urban sewage contaminate water and soil by the process of seepage and leaching or irrigation with wastewater leads to depletion of groundwater and soil quality. High concentration of metals and other contaminants in the soil and groundwater may be due to continuous and long-term disposal of wastewater containing metals from industrial units leading to health hazards (Wuana and Okieimen 2011). Therefore, applying geographical and geostatistical techniques with an integrated approach could be more effective ways in environmental monitoring and assessment of soil and water contamination to ensure environmental and health safety.

Conclusion

Groundwater and soil quality parameters of water and soil samples varied with different sites of the selected study area, indicate about 13.3% of the sites found to have good soil health with minimum contamination level followed by 40% of sites with moderate contamination; however, 46.6% of sites shown high level of contamination of soil. Evaluating WQI and SQI values in the present study offers insightful information about site-wise variation pattern of quality parameters including metals identifying the sites with high level of contamination to opt appropriate strategies and mitigation measures to ensure preserving groundwater and soil quality. Further, a study concludes that contamination of water and soil with metals and other contaminants leads to depletion of quality parameters which affects nutrients cycling in the aquatic and terrestrial ecosystem with more imbalances in availability of NPK. GIS-based WQI maps provide more description of sites in categorizing contaminated regions to ensure safe water supply and developing wastewater treatment facilities for sustainable urban planning. Besides, water and soil quality assessment using GIS and geostatistical technique provide regional and spatial variability of contaminants with their correlation to establish standards of soil health and drinking for effective natural resource management in a particular region. Therefore, the present study could be a new insight in in environmental monitoring involving quantitative and qualitative assessment of water and soil quality for sustainable resource utilization and conservation applying geographical and geostatistical techniques.

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Author contribution All authors contributed to the study conception and design. Sampling of water and soil samples, analysis, and drafting of manuscript were performed by J. Khan and G. Gupta. All authors commented on previous versions of the manuscript. Hypothesis and designing of the experiment were done by N. K. Singh; data analysis and improving the manuscript were done by V.N. Bhave and V. Bhardwaj; map designing and statistical analysis were done by P. Upreti and R. Singh; and geophysical analysis and editing were done by A. K. Sinha. All authors read and approved the final manuscript.

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Declarations

Ethical approval This is not applicable.

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Consent to publish All authors are mutually agreed to publish the manuscript in the journal ESPR.

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Research Article

Linear diophantine uncertain linguistic-based prospect theory approach for performance evaluation of islanded microgrid-system scenarios

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Abstract

Renewable-energy-based hybrid microgrids can aid in achieving one of the United Nations Sustainable Development Goals, i.e. 'Affordable and clean energy'. However, experts may be faced with the challenge of selecting the best one for the electrification of an area. To avoid the challenge and realize the ultimate goal of the United Nations, the present study, therefore, proposes a novel prospect theory-based decision-making approach to help experts in opting for the best microgrid scenario. The proposed decision-making framework considers the risk appetite of the decision-maker, a quintessential aspect of the process. Linear diophantine uncertain linguistic sets are used to model the linguistic evaluations from the experts. The information from different experts is aggregated using a linear diophantine uncertain linguistic power Einstein-weighted geometric operator. Finally, the prospect-theory-based TOmada de Decisao Interativa Multicriterio approach is employed to evaluate the performance of the available microgrid scenarios and hence opt for the best microgrid scenario. The proposed framework has been used to evaluate the performance of seven possible microgrid scenarios and hence select the best one that can be implemented for rural electrification of a remote village in Assam, India. The microgrid scenario consisting of a photovoltaic–wind turbine–fuel cell–battery converter (MG_3) has been revealed to be the best scenario among the seven considered microgrid scenarios. The validity of the obtained ranking results has been adjudged through a comprehensive evaluation regarding the attenuation factor and the weights of the criteria. Moreover, previous case studies have also been solved using the proposed methodology and the results reveal a good correlation between the obtained ranking results.

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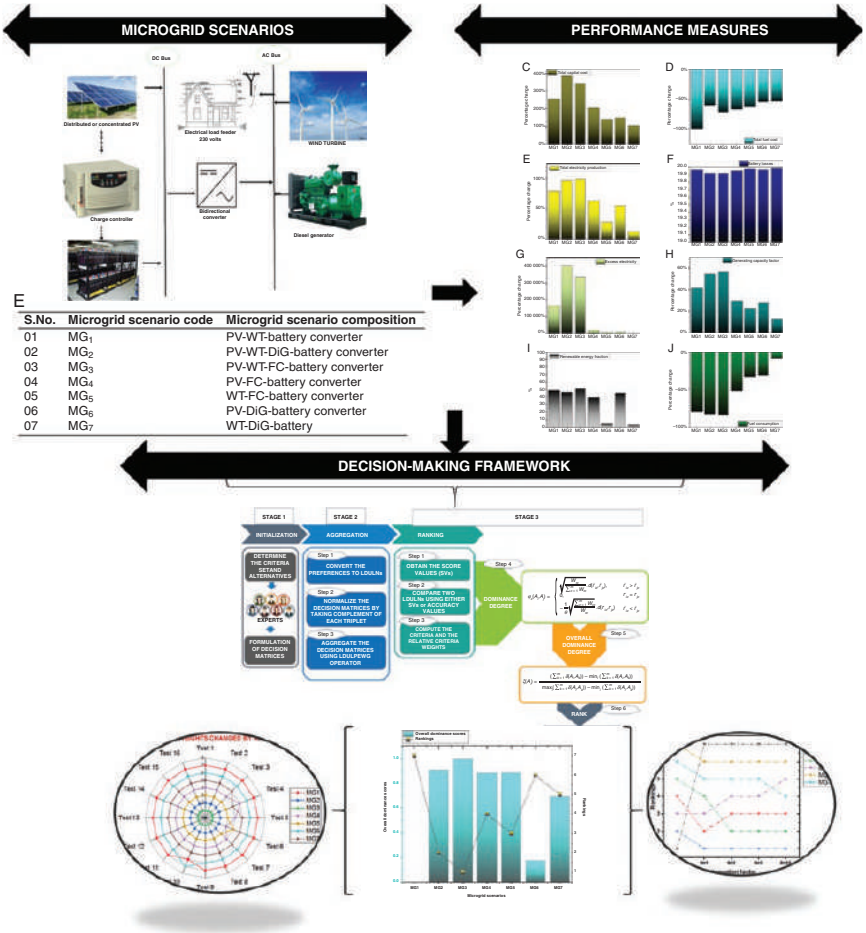
Graphical Abstract



Keywords: distributed energy and smart grid; energy and environment; islanded microgrid

Introduction

There has been a surge in energy demand owing to fast-paced technological advancements and industrialization. The increasing demand for energy can be met with the increased generation of electricity. Total electricity demand is expected to grow by ≤30% in 2040 as compared with 2015. Conventional energy sources that rely on fossil fuels amount to >75% of total electricity generation [1]. However, the consumption of more fossil fuels results in the increased emission of harmful greenhouse gases. This negatively affects the prospects of climate change and global warming [2]. Furthermore, following the estimates of the World Bank [3], 22.6% of the rural and 3.1% of the urban population had no access to electricity in 2016. The situation has catalysed the policymakers to research in the direction of meeting the energy demand through the proposition of sustainable and green sources of energy.

To avoid the limitations of conventional energy sources, the integration of renewable energy sources (RESs), such as solar, wind, biomass, etc., is the best option. It provides eco-friendly energy to meet the continuously increasing energy demand. It has been estimated that RESs contributed around two-thirds of the generated capacity in the year 2018 [4]. This estimate itself is worth evidencing the critical role that renewable energy has been playing to provide green and sustainable energy for all. Given the importance of RESs, the International Renewable Energy Agency (IRENA) [1] has outlined the global objective to improve the contribution of RESs to 85% by 2050, which was 25% in the year 2017. RESs will not only meet the challenges associated with global warming but will also contribute towards socio-economic development by creating jobs in society.

However, there is a wide range of challenges associated with the implementation of RESs, including safety and reliability aspects. This may be attributed to the fluctuation and intermittent characteristics exhibited by RESs. The intermittency can be shadowed through the aid of energy-storage systems (ESSs). However, ESSs often contribute negatively to the economic aspect of the project. As such, hybrid renewable-energy-based microgrid (HREM) platforms are one of the probable solutions that provide an effective trade-off between cost and reliability.

Selection of the best possible microgrid scenario for an area depends on techno-economic, social and environmental aspects. A systematic and scientific approach can aid in the judicious selection of the best possible scenario. Multicriteria decision-making (MCDM) tools are one of the possible approaches that can help address the challenge that ranks the alternatives under the influence of conflicting criteria or performance scores. The decision on the best possible scenario should be made with due consideration to the decision-maker's loss-aversion behaviour during the decision-making process. Kahneman and Tversky [5] proposed prospect theory, which considers the loss-averse behaviour of the decision-maker. The MCDM approach in the form of TOmada de

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Decisao Interativa Multicriterio (TODIM) was proposed by Gomes [6] and considers the potential ability of decision-makers to be risk-averse. The loss or risk aversion is reflected by the attenuation factor in the TODIM approach while making the evaluations.

Apart from the behavioural aspect, precise modelling of linguistic evaluation is also essential to facilitating an accurate decision-making process. The vagueness associated with information has been well managed through the proposition of fuzzy sets [7], wherein the linguistic preferences of experts were modelled through the use of membership functions rather than through non-fuzzy numbers. The expounded theory only comprised the grade of truth and therefore the evaluations were modelled as [0, 1]. However, the proposed fuzzy-set theory failed in its purpose in situations in which the degree of falsity also needed to be considered apart from the degree of truth. As such, Atanassov [8] proposed the concept of intuitionistic fuzzy sets that considered both the grade of truth and falsity with the condition that the sum of grades varies between 0 and 1. The aforementioned rule, however, deters the modelling of preferences wherein experts provide such grades of falsity and truth that the summation of their squares lies between 0 and 1. This was taken care of through the proposal of Pythagorean fuzzy sets by Yager [9]. Again, in certain situations, the falsity and truth grades may even not follow any of the above rules and instead the summation of their q-th power may lie between 0 and 1. This concern was addressed through the proposition of q-rung orthopair fuzzy sets by Yager [10]. Recently, Riaz and Hashmi [11] proposed a linear diophantine fuzzy set (LDFS) that did away with the situations in which the data endorsed by the experts regarding the falsity and truth grade did not conform to the aforementioned rules for fuzzy sets, intuitionistic fuzzy sets, Pythagorean fuzzy sets and q-rung orthopair fuzzy sets. They associated two parameters with the falsity and truth grade, and the summation of the product of the respective parameters and their grade lay between 0 and 1. Mahmood *et al.* [12] proposed the improvising of LDFSs in the form of a linear diophantine uncertain linguistic set that was revealed to be more flexible and generalized in comparison with the aforementioned information sets.

In addition to modelling the preferences of experts, aggregation of the information received from different experts also forms a quintessential element of the decision-making process. Researchers have introduced numerous aggregation operators for different information modelling. Aggregation operators for fuzzy sets were proposed by Gassert [13], Shahzadi *et al.* [14], Liu and Wang [15], etc. Liu *et al.* [16], Garg [17], etc., proposed aggregation operators for intuitionistic fuzzy (IF) sets. For Pythagorean fuzzy sets, aggregation operators were proposed by Garg [18], Wei [19], etc. He *et al.* [20], Akram *et al.* [21], etc., proposed aggregation operators for q-rung fuzzy sets. Power Einstein aggregation operators were proposed by Mahmood *et al.* [12] for linear diophantine uncertain linguistic fuzzy (LDULF) sets. The power of Einstein aggregation operators accounts for the interaction between the truth and falsity grades, which is critically important in arriving at correct decision results. Hence, in the present study, the fusion of information endorsed by different experts has been processed by employing a linear diophantine uncertain linguistic power Einstein-weighted geometric (LDULPEWG) operator.

The contributions and novelties of the presented work can be summarized as follows:

(i) A dedicated decision-making methodology has been proposed that takes into account the risk-averse psychological characteristic behaviour of the decision expert, employs LDULF sets to model the linguistic information by the experts and aggregates the linguistic evaluations through the LDULPEWG operator.
(ii) The proposed performance-appraisal framework has been applied to suitably select the best microgrid scenario to be implemented for rural electrification in India. A total of seven possible scenarios have been considered.
(iii) The selection of the best HREM has been adjudged with utmost importance to all the prominent components of sustainability, i.e. techno-economic and socio-environmental considerations.

The remainder of the work has been structured as follows. The literature review associated with HREM systems is presented in Section 1 of the work. Section 2 discusses the proposed decision-making approach. Section 3 discusses the case study related to the selection of the best possible microgrid scenario. The techno-economic and environment modelling as well as the simulations of the considered scenarios have been processed in Section 3 of the work. The application of the proposed decision-making tool to select the best scenario is also been depicted in Section 3 of the work. The validation of the ranking results has also been presented in Section 4. The work ends with the concluding remarks in Section 5.

1 Literature review

1.1 Literature on HREM systems

There has been a wide array of research reports on off-grid and on-grid microgrid systems incorporating distinct renewable energy resources. These reports focus on issues such as energy management and control, sizing and optimization [22–24]. Araoye *et al.* [25] carried out a techno-economic analysis for a diesel–biogas hybrid microgrid system. Simulink® was used to determine the methane yield of the reactor and HOMER was employed to perform the optimization. The design and optimization of the islanded hybrid microgrid were assayed regarding the load dispatch strategies for four divisions located on the northern side of Bangladesh [26]. HOMER was used for the optimization of the considered microgrids, while MATLAB®/Simulink® was used to adjudge the feasibility of the microgrids adopted. Jahangiri *et al.* [24] investigated four possible combinatorial scenarios of energy sources for the generation of electricity for ZarrinShahr located in the Isfahan Province of Iran. The economic optimization performed using the HOMER simulation revealed the superiority of the HREM system for the aforementioned area only when the place under consideration was <2.58 km from the national grid. Nömm *et al.* [27] proposed a techno-economic energy-flow model to analyse the investment risks associated with standalone microgrids in Sweden. Mandal *et al.* [28] proposed an HREM system comprising a solar photovoltaic (PV) system, wind and diesel (DiG) generators and battery storage for a northern region of Bangladesh. The techno-economic feasibility of the aforementioned region was carried out using HOMER software. Abo-Elyousr and Elnozahy [29] carried out a feasibility analysis of an HREM system for three isolated areas in Egypt using different fuel options. The optimal sizing of the distributed energy resources was carried out through the employability of the ant colony optimization algorithm. Luta and Raji [30] carried out a comparative analysis between grid extension and an off-grid hybrid renewable-energy system for a farming village in South Africa. A comparative analysis was performed between four different optimization techniques, i.e. the genetic algorithm, particle

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swarm optimization, teaching–learning-based optimization and butterfly particle swarm optimization to deduce the optimal hybrid renewable-energy system in India [31]. Six different cases were considered to obtain the most efficient configuration of all. The teaching–learning-based optimization technique was reported to be better in all the optimization techniques. Bastholm and Fiedler [32] carried out an investigation on the economic viability of off-grid microgrids for electrification in Tanzania. The off-grid microgrid system was revealed to be suitable only in the case of a grid with blackouts. Kumar and Verma [33] proposed a generically adaptable model for the techno-economic optimization of an HREM system. Mixed-integer linear programming was employed to meet the objective. Ramli *et al.* [34] explored the techno-economic potential of hybrid wind/solar energy systems for Saudi Arabia using MATLAB® and HOMER software. The feasibility investigation on the employability of PV-based renewable-energy microgrid systems was carried out for Sarwak, Malaysia, by Das *et al.* [35]. Two systems with and without fuel cells (FCs) were compared with the traditional diesel-based system and the superiority of the renewable-energy-based system without FCs was established. Mandal *et al.* [28] explored the potential of a hybrid energy system comprising a wind turbine (WT), PV system, diesel generator and battery storage for a northern region of Bangladesh.

On the basis of the studied literature, the following points could be summarized: (i) When a comparative analysis between HREM systems and conventional energy systems is done, the microgrid systems have been revealed to be techno-economically superior to their conventional counterparts. (ii) The key influential factors that determine the right hybrid renewable-energy systems are the environmental and technical aspects, such as load-demand characteristics. (iii) An array of researchers have directed their attention towards investigating the techno-economic viability of the proposed microgrid systems. (iv) There are limited reports on the dedicated decision-making framework that can aid in the precise selection of the best microgrid scenario and hence promote strategic planning and implementation of microgrid systems.

Therefore, in the present work, a novel decision-making approach has been proposed to assess the different microgrid scenarios. This would help to make a judicious choice for the best microgrid scenario for rural electrification in India. This has been accomplished with due regard to the technical, economic and socio-environmental parameters.

1.2 Literature on the TODIM method

The decision-making process involves making a judicious choice of the best alternative from a set of feasible alternatives. The process becomes more complex as the best alternative needs to be selected with due consideration to numerous performance metrics, also known as criteria. Such criteria are often conflicting in nature, thereby complicating the decision-making process. Numerous decision-making frameworks have been proposed to address decision-making problems in various domains systematically and scientifically. The accuracy of the results depends significantly on the accuracy of modelling the collected linguistic information. To deal with the uncertainty associated with the information, Zadeh [7] used fuzzy-set theory to address the different decision-making problems. However, the proposed fuzzy-set tools fail to consider the hesitation of the expert while providing the evaluations.

In addition to the accurate modelling of expert preferences, it is also important to consider the risk appetite of the decision experts. The TODIM (an acronym in Portuguese for the multicriteria interactive and multicriteria decision-making approach) was proposed by Gomes and Lima [36] and has the potential ability to take into account the risk appetite of decision experts. Several extended fuzzy versions of TODIM methodologies have been proposed by the scientific community, such as interval-valued intuitionistic fuzzy (IVIF) TODIM [37], hesitant fuzzy TODIM [38], complex-IVIF TODIM [39], single-valued neutrosophic fuzzy TODIM [40], etc. The various TODIM versions have been investigated for their potential to address a wide array of decision-making problems such as the selection of strategies for industry 4.0 (fourth industrial revolution) [41], the selection of the optimal configuration for green products [42] and the performance evaluation of potential vegetable oils used in concentrated solar power plants [41]. Tian *et al.* [43] have contributed a comprehensive review article on the same in this regard. Although numerous extensions of the TODIM method have been proposed, they have failed to consider the highlighted problems associated with the algorithmic rules for the truth and falsity grades. This could be well addressed through the extension of the TODIM approach under a linear diophantine uncertain linguistic environment. Also, the interaction between the falsity and truth grades can be realized through the LDULPEWG operator.

Therefore, one of the main objectives of the present work is to provide an integrated performance-appraisal framework that eliminates the aforementioned lacuna. Within the proposed framework, the information is modelled using LDULF sets, aggregated using the LDULPEWG operator, and the performance of the microgrid scenarios is appraised through the employability of the TODIM approach. The proposed framework will be discussed in Section 2 of the presented work.

2 Proposed performance-appraisal framework

The present section enumerates the basic definitions associated with the classical TODIM approach, the linear diophantine uncertain linguistic sets and the different aggregation operators (AOs): the power AO and Einstein t-norm and t-conorm operations and the LDULF power Einstein operators. The proposed approach will be discussed towards the end of this section.

2.1 Classical TODIM approach

The different phases involved in the TODIM approach are described next.

Procedural Step 1: As a first step, a decision matrix $P = [p_{ij}]_{m\times n}$ is formulated. The formulated decision matrix is then standardized and can be denoted as $D = [d_{ij}]_{m\times n}$.

Procedural Step 2: Equation (1) is used next to arrive at the relative weights of the criteria. This is done with the aid of respective criteria weights (w_j). The weight of the reference criteria (w_r) is usually the maximum among the criteria weights:

$$w_{jr} = \frac{w_j}{w_r} \tag{1}$$

Procedural Step 3: Equation (2) provides the formulation for the calculation of the dominance degree $\varnothing_j(A_i, A_k)$ of an alternative A_i over the alternative A_k for a given criterion C_j:

$$\varnothing_j(A_i,\ A_k) = \begin{cases} \sqrt{(d_{ij} - d_{kj}) \cdot \frac{w_{jr}}{\sum_{j=1}^{n} w_{jr}}}, & d_{ij} - d_{kj} > 0 \\ 0, & d_{ij} - d_{kj} = 0 \\ -\frac{1}{\theta}\sqrt{(d_{ij} - d_{kj}) \cdot \frac{\sum_{j=1}^{n} w_{jr}}{w_{jr}}}, & d_{ij} - d_{kj} < 0 \end{cases} \tag{2}$$

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The risk appetite of the expert is captured by the attenuation factor (θ) and is >0. The parameter signifies the loss-aversion preference of the decision-maker.

Procedural Step 4: Equation (3) reflects on the formulation of the dominance score of the alternative and is used to calculate the dominance scores for each of the alternatives considered within this step of the methodology:

$$T\left(A_i, A_k\right) = \sum_{k=1}^{m} \varnothing_j\left(A_i, A_k\right) \tag{3}$$

Procedural Step 5: In this step of the TODIM approach, the calculations for the overall dominance score (ODS) are processed. To obtain the same, we use the formulation in Equation (4):

$$\xi\left(A_i\right) = \frac{\sum_{k=1}^{m} T\left(A_i, A_k\right) - min_{i\epsilon M}\left\{\sum_{k=1}^{m} T\left(A_i, A_k\right)\right\}}{max_{i\epsilon M}\left\{\sum_{k=1}^{m} T\left(A_i, A_k\right)\right\} - min_{i\epsilon M}\left\{\sum_{k=1}^{m} T\left(A_i, A_k\right)\right\}} \tag{4}$$

Procedural Step 6: The identified set of alternatives is evaluated based on the ODS obtained using Equation (4). The highest ODS is associated with the top-ranking of the alternatives amongst the considered ones.

2.2 The linear diophantine uncertain linguistic set

Definition 1: An LDFS [11] is understood as follows:

$$L_{LD} = \left\{\frac{\left(y,\ \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)}{y\ \epsilon\ Y}\right\} \tag{5}$$

In the above formulation, the following rule follows: $0 \le \delta_{LMG}u_{LMG}\left(y\right) + \gamma_{LNG}\ v_{LNG}\left(y\right) \le 1$ and $0 \le \delta_{LMG} + \gamma_{LNG} \le 1$. The refusal grade is expressed as $\Psi_{L_{LD}}\ \pi\ \left(y\right)_{L_{LD}}$ and is given as $\Psi_{L_{LD}}\ \pi\ \left(y\right)_{L_{LD}} = 1 - \ \left(\delta_{LMG}u_{LMG}\left(y\right) + \gamma_{LNG}\ v_{LNG}\left(y\right)\right)$. Therefore, the linear diophantine fuzzy number is elucidated as.

Definition 2: A linguistic term set (LTS) [44] can be comprehended as follows:

$$R = \left\{r_1, r_2,\ \ldots\ldots\ldots r_{k-1}\right\} \tag{6}$$

where k needs to be odd and should follow the conditions below:

(i) If $k > k'$, then $r_k > r_{k'}$
(ii) neg $(r_k) = r_{k'}$ given that $k + k' = k + 1$
(iii) If $k \ge k'$, max $(r_k, r_{k'}) = r_k$ and if $k \le k'$, max $(r_k, r_{k'}) = r_{k'}$.

$r' = [r_a,\ r_b]$ is known as the uncertain linguistic variable (ULV) where $r_a, r_b\ \epsilon$ R and are the lower and upper limits, respectively.

Definition 3: For any two ULVs: $r'_1 = [r_{a1}, r_{b1}]$ and $r'_2 = [r_{a2}, r_{b2}]$, the following algebraic operations can be realized:

$$r'_1 \oplus r'_2 = [r_{a1}, r_{b1}] \oplus [r_{a2}, r_{b2}] = [r_{a1+a2}, r_{b1+b2}], \tag{7}$$

$$r'_1 \oplus r'2 = [r_{a1}, r_{b1}] \oplus [r_{a2}, r_{b2}] = [r_{a1\times}r_{a2}, r_{b1\times b2}], \tag{8}$$

$$\Phi r'_1 = \Phi[r_{a1}, r_{b1}] = [r_{\Phi * a1}, r_{\Phi * b1}], \tag{9}$$

$$\left(r'_1\right)^{\Phi} = \left[r_{(a1)}{}^{\Phi}, r_{(b1)}{}^{\Phi}\right] \tag{10}$$

Next, a linear diophantine uncertain linguistic set (LDULS) has been defined.

Definition 4: An LDULS (L_{LDULS}) [12] can be elaborated as follows:

$$L_{LDULS} = \left\{\frac{y\ \left[\left[\ r_{\varnothing\ (Y)},\ r_{\theta\ (Y)}\right],\ \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right]}{y\ \epsilon\ Y}\right\} \tag{11}$$

Therefore, the linear diophantine uncertain linguistic number (LDULN) can be expressed as: $L_{LD} = \left(\left[\ r_{\varnothing\ (Y)},\ r_{\theta\ (Y)}\right],\ \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$

Definition 5: The following algebraic operations in Equations (12–15) [12] can be performed for any two LDULNs, $L_{LD} = \left(\left[r_{L-\varnothing(Y)}, r_{L-\theta(Y)}\right], \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$ and $\left(\left[M_{LD} = \left(\left[r_{M-\varnothing(Y)},\ r_{M-\theta(Y)}\right], \left(u_{MMG}\left(y\right),\ v_{MNG}\left(y\right)\right), \left(\gamma_{MMG}\delta_{MNG}\right)\right)\right.$:

$$L_{LD} \oplus M_{LD} = \begin{bmatrix} \left[r_{L-\varnothing(Y)+M-\varnothing(Y),}\ r_{L-\theta(Y)+M-\theta(Y)}\right], \\ \left(u_{LMG} + u_{MMG} - u_{LMG}u_{MMG}, v_{MMG}v_{MMG}\ \right), \\ \left(\gamma_{LMG} + \gamma_{MMG} - \gamma_{LMG}\gamma_{MMG},\ \delta_{LMG}\delta_{MMG}\right) \end{bmatrix} \tag{12}$$

$$L_{LD} \otimes M_{LD} = \begin{bmatrix} \left[r_{L-\varnothing(Y)*M-\varnothing(Y),}\ r_{L-\theta(Y)*M-\vartheta(Y)}\right], \\ \left(u_{MMG}u_{MMG},\ v_{LMG} + v_{MMG} - v_{LMG}v_{MMG},\ \right), \\ \left(\gamma_{LMG}\gamma_{MMG},\ \delta_{LMG} + \delta_{MMG} - \delta_{LMG}\delta_{MMG}\right) \end{bmatrix} \tag{13}$$

$$\lambda L_{LD} = \begin{bmatrix} \left[r_{L-\varnothing(Y)\times\lambda}, r_{L-\theta(Y)\times\lambda}\ \right], \\ \begin{bmatrix} \left(1 - \left(1 - u_{LMG}\left(y\right)\right)^{\lambda}, \left(v_{LNG}\left(y\right)\right)^{\lambda}\right), \\ \left(1 - \left(1 - \alpha_{LMG}\left(y\right)\right)^{\lambda}, \left(\beta_{LNG}\left(y\right)\right)^{\lambda}\right) \end{bmatrix} \end{bmatrix} \tag{14}$$

$$L_{LD}^{\lambda} = \left[r_{(L-\varnothing(Y))^{\lambda}}, r_{(L-\theta(Y))^{\lambda}}\ \right], \tag{15}$$

$$\begin{bmatrix} \left(u_{LNG}\left(y\right)\right)^{\lambda}, \left(1 - \left(v_{LMG}\left(y\right)\right)^{\lambda}\right), \\ \left(\left(\alpha_{LNG}(y)\right)^{\lambda}, 1 - \left(1 - \beta_{LMG}\left(y\right)\right)^{\lambda}\right) \end{bmatrix}$$

Definition 6: The expected value [12] for any two LDULN, $L_{LD} = \left(\left[r_{L-\varnothing(Y)}, r_{L-\theta(Y)}\right], \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$ and $M_{LD} = \left(\left[M_{LD} = \left(\left[r_{M-\varnothing(Y)},\ r_{M-\theta(Y)}\right], \left(u_{MMG}\left(y\right),\ v_{MNG}\left(y\right)\right), \left(\gamma_{MMG}\delta_{MNG}\right)\right)\right)$ can be acquired through the following Equation (16):

Definition 7. The accuracy value [12] for any two LDULN $L_{LD} = \left(\left[r_{L-\varnothing(Y)}, r_{L-\theta(Y)}\right], \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$ and $M_{LD} = \left(\left[r_{M-\varnothing(Y)},\ r_{M-\theta(Y)}\right], \left(u_{MMG}\left(y\right),\ v_{MNG}\left(y\right)\right), \left(\gamma_{MMG}\delta_{MNG}\right)\right)$ can be acquired through the following Eq. (17)

$$\xi\left(L_{LD}\right) = \xi\ \left(L_{LD}\right) = r_{\left(\left(U\left(a_1\right)+V\left(a_1\right)\right)\times\left(\frac{1}{2}\right)\left(u_{LMG}(y)+tv_{ANG}(y)q+h(\delta+\gamma)\right)/4\right.} \tag{17}$$

Definition 8. For any two LDULN $L_{LD} = \left(\left[r_{L-\varnothing(Y)}, r_{L-\theta(Y)}\right], \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$ and $M_{LD} = \left(\left[r_{M-\varnothing(Y)},\ r_{M-\theta(Y)}\right], \left(u_{MMG}\left(y\right),\ v_{MNG}\left(y\right)\right), \left(\gamma_{MMG}\delta_{MNG}\right)\ \right)$ the following can be summarized concerning their comparison [12].

(1) If $E\left(L_{LD}\right) < E\left(M_{LD}\right)$, then $L_{LD} < M_{LD}$
(2) If $E\left(L_{LD}\right) > E\left(M_{LD}\right)$, then $L_{LD} > M_{LD}$
(3) $E\left(L_{LD}\right) > E\left(M_{LD}\right)$, then
  (i) If $\xi\left(L_{LD}\right) < \xi\left(M_{LD}\right)$, then $L_{LD} < M_{LD}$
  (ii) If $\xi\left(L_{LD}\right) > \xi\left(M_{LD}\right)$, then $L_{LD} > M_{LD}$
  (iii) If $\xi\left(L_{LD}\right) = \xi\left(M_{LD}\right)$, then $L_{LD} \simeq M_{LD}$

2.3 The power aggregation operator and the Einstein t-norm and t-conorm operations

Definition 9: The power aggregation (PA) [44] operator is elaborated by:

$$PA\left(L_{LD-1}, L_{LD-2}, \ldots\ldots\ldots\ldots, L_{LD-n}\right) = \frac{\sum_{i=1}^{n}\left(1 + T\left(L_{LD-i}\right)\right) * L_{LD-i}}{\sum_{i=1}^{n}\left(1 + T\left(L_{LD-i}\right)\right)} \tag{18}$$

where $T\left(L_{LD-i}\right) = \sum_{j=1}^{n} \sup\left(L_{LD-i},\ L_{LD-j}\right)$ and $Sup\left(L_{LD}^{k},\ L_{LD}^{q}\right) = 1 - d\left(L_{LD}^{k},\ L_{LD}^{q}\right)$ where d represents the distance between two LDULNs

Definition 10 The basic Einstein t-norm and t-conorm operations can be elucidated for two LDULN $L_{LD} = \left(\left[r_{L-\varnothing(Y)}, r_{L-\theta(Y)}\right], \left(u_{LMG}\left(y\right),\ v_{LNG}\left(y\right)\right), \left(\gamma_{LMG}\delta_{LNG}\right)\right)$ and $M_{LD} = \left(\left[r_{M-\varnothing(Y)},\ r_{M-\theta(Y)}\right], \left(u_{MMG}\left(y\right),\ v_{MNG}\left(y\right)\right), \left(\gamma_{MMG}\delta_{MNG}\right)\ \right)$ as follows [12]:

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$$L_{LD} \otimes M_{LD} = \left(\begin{array}{c} \left[r_{L-\varnothing(Y)+M-\theta(Y)}, r_{L-\theta(Y)+M-\theta(Y)} \right], \\ \left(\frac{u_{LMG}(y)+u_{MMG}(y)}{1+(u_{LMG}(y)).(u_{MMG}(y))}, \frac{v_{LNG(y)}.v_{MNG}(y)}{1+(1-v_{LNG(y)}).(1-v_{MNG}(y))} \right), \\ \left(\frac{\gamma_{LMG}+\gamma_{MMG}}{1+(\gamma_{LMG}).(\gamma_{MMG})}, \frac{\delta_{LNG}.\delta_{MNG}}{1+(1-\delta_{LNG}).(1-\delta_{MNG})} \right) \end{array} \right) \quad (19)$$

$$\Phi\ L_{LD} = \left(\begin{array}{c} \left[r_{\Phi\ .L-\varnothing(Y)}, r_{\Phi\ .L-\theta(Y)} \right], \\ \left(\frac{(1+u_{LMG}(y))^{\Phi}-(1-u_{LMG}(y))^{\Phi}}{(1+u_{LMG}(y))^{\Phi}+(1-u_{LMG}(y))^{\Phi}}, \frac{2(v_{LNG}(y))^{\Phi}}{(2-v_{LNG}(y))^{\Phi}+(v_{LNG}(y))^{\Phi}} \right), \\ \left(\frac{(1+\gamma_{LMG})^{\Phi}-(1-\gamma_{LMG})^{\Phi}}{(1+\gamma_{LMG})^{\Phi}+(1-\gamma_{LMG})^{\Phi}}, \frac{2(\delta_{LNG})^{\Phi}}{(2-\delta_{LNG})^{\Phi}+(\delta_{LNG})^{\Phi}} \right) \end{array} \right) \quad (20)$$

$$L_{LD}^{\Phi} = \left(\begin{array}{c} \left[r_{L-\varnothing(Y)^{\Phi}}, r_{L-\theta(Y)^{\Phi}} \right], \\ \left(\frac{2U_{LMG}(y))^{\Phi}}{(2-U_{LMG}(y))^{\Phi}+(U_{LMG}(y))^{\Phi}}, \frac{(1+V_{LNG}(y))^{\Phi}-(1-V_{LNG}(y))^{\Phi}}{(1+V_{LNG}(y))^{\Phi}+(1-V_{LNG}(y))^{\Phi}} \right), \\ \left(\frac{2(\gamma_{LMG})^{\Phi}}{(2-\gamma_{LMG})^{\Phi}+(\gamma_{LMG})^{\Phi}}, \frac{(1+\delta_{LNG})^{\Phi}-(1-\delta_{LNG})^{\Phi}}{(1+\delta_{LNG})^{\Phi}+(1-\delta_{LNG})^{\Phi}} \right) \end{array} \right) \quad (21)$$

2.4 The LDULF power Einstein operators

$$\text{LDULFPEWA}\ (L_{LD-1}, \quad L_{LD-2}, \quad \ldots, \quad L_{LD-n}) = \frac{\otimes_{\varepsilon i=1}^{n} w_k\,(1+T\,(L_{LD-i}))*L_{LD-i}}{\sum_{i=1}^{n} w_k\,(1+T\,(L_{LD-i}))} \quad (22)$$

$$\text{LDULFPEWA}\ (L_{LD-1}, \quad L_{LD-2}, \quad \ldots, \quad L_{LD-n}) = \otimes x_{\varepsilon i=1}^{n} \left(\frac{w_k\,(1+T\,(L_{LD-i}))*L_{LD-i}}{\sum_{i=1}^{n} w_k(1+T\,(L_{LD-i}))} \right) \quad (23)$$

where $T(L_{LD-i}) = \sum_{j=1}^{n} \sup(L_{LD-i}, L_{LD-j})$, and sup (L_{LD-i}, L_{LD-j}) is support for L_{LD-i} *from* L_{LD-j}.

Definition 11 The linear Diophantine uncertain linguistic fuzzy power Einstein-weighted geometric (**LDULFPEWG**) can be expressed using Eq. (24) as follows [12].

$$\text{LDULFPEWG}\ (L_{LD-1}, \quad L_{LD-2}, \quad \ldots, \quad L_{LD-n}) = \otimes_{\varepsilon i=1}^{n} (L_{LD-i})^{w_i(1+(L_{LD-i}))/\sum_{i=1}^{n} w_i(1+(L_{LD-i}))} \quad (24)$$

where $T(L_{LD-i}) = \sum_{\substack{j=1 \\ j \neq i}}^{n} \sup(L_{LD-i}, L_{LD-j})$ and sup (L_{LD-i}, L_{LD-j}) is support for L_{LD-i} *from* L_{LD-j} and $u = (u_1, u_2, \ldots\ldots\ldots\ldots, u_n)^T$ is known as the weighting vector of the $(L_{LD-1}, L_{LD-2}, \ldots\ldots\ldots\ldots, L_{LD-n})$, such that $u_i \in [0, 1]$, $\sum_{i=1}^{n} u_i = 1$.

2.5 The proposed approach

The ensuing discussion emphasizes the procedural steps associated with the LDULPEWG fuzzy TODIM approach. The framework comprises the following stages: initialization, aggregation and ranking. The procedural steps associated with the proposed approach are depicted in Fig. 1.

In the *initialization stage* (Stage 1) of the proposed framework, the alternative set $\{A_1, A_2 \ldots A_m\}$ and the set for performance measures $\{C_1, C_2 \ldots C_n\}$ are identified to assess the identified alternatives. Experts are selected based on their expertise in the related domain to facilitate the performance-appraisal process. The evaluations are collected from the chosen experts and decision matrices $\{D^k = (d_{ij}^k)_{m\times n}\ (k = 1, 2, \ldots q)\}$ for each of the q experts are formulated that encompass linguistic preferences. The weights $\{X^k = (x_{ij}^k)_{m\times n}\ (k = 1, 2, \ldots q)\}$ for the experts are provided subjectively based on their quantum of experience. However, the assignment of weights to experts must follow the condition: $\sum_{k=1}^{q} w^k = 1$.

The second stage is the *aggregation stage*, which starts with the conversion of linguistic evaluations (Step 1) in terms of LDULNs. Let the converted decision matrices be represented as $\{X^k = (x_{ij}^k)_{m\times n}\ (k = 1, 2, \ldots q)\}$, where x_{ij}^k represents the LDULN for the corresponding linguistic preference provided by the q-th expert. Subsequently, the decision matrices are normalized to have the same type of data. Equations (25) and (26) can be employed for the beneficial and non-beneficial criteria, respectively:

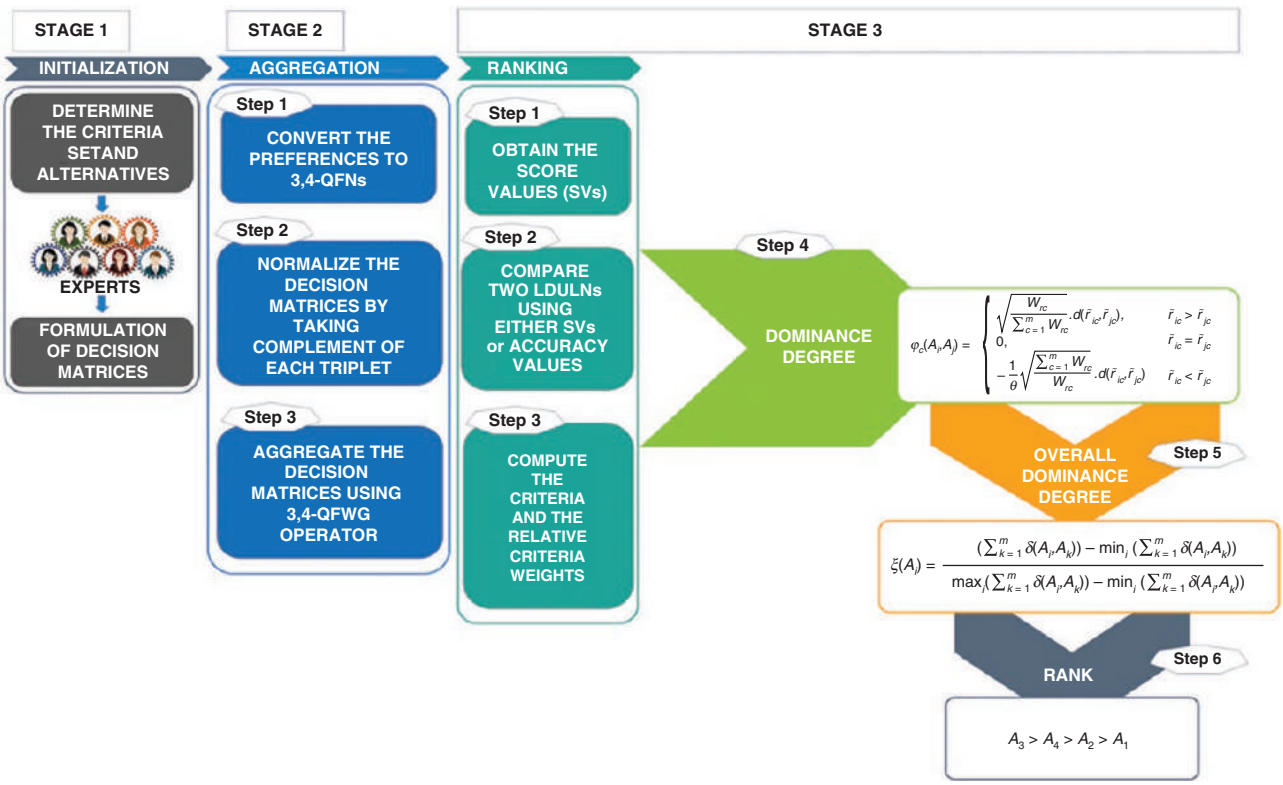

Fig. 1: Flowchart for the proposed approach

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$$x_{ij}^{k} = \left[S_{\theta(X)}, S_{\tau(X)}\right], (u_{AMG},\ v_{ANG}), (\alpha_{AMG},\ \beta_{ANG}) \tag{25}$$

$$x_{ij}^{k} = \left[S_{\tau(X)}, S_{\theta(X)}\right], (v_{ANG},\ u_{AMG}), (\beta_{ANG},\ \alpha_{AMG}) \tag{26}$$

In Step 2 of the second stage of the framework, the supports, i.e. $Sup\left(x_{ij}^{k},\ x_{ij}^{q}\right)$, are obtained through the formulation depicted in Equation (27):

$$Sup\left(x_{ij}^{k},\ x_{ij}^{q}\right) = 1 - d\left(x_{ij}^{k},\ x_{ij}^{q}\right) \tag{27}$$

where d represents the distance between two LDULNs $\left[S_{A-\theta(X)}, S_{A-\tau(X)}\right], (u_{AMG},\ v_{ANG}), (\alpha_{AMG},\ \beta_{ANG})$ and $\left[S_{B-\theta(X)}, S_{B-\tau(X)}\right], (u_{BMG},\ v_{BNG}), (\alpha_{BMG},\ \beta_{BNG})$ that can be obtained through Equation (28):

$$d\left(x_{ij}^{k},\ x_{ij}^{q}\right) = \frac{1}{4(L-1)}\left[\begin{vmatrix}\{(1+u_{AMG}-v_{ANG})(1+\alpha_{AMG}-\beta_{ANG})A-\theta(X)\}- \\ \{(1+u_{BMG}-v_{BNG})(1+\alpha_{BMG}-\beta_{BNG})B-\theta(X)\}\end{vmatrix} + \begin{vmatrix}\{(1+u_{AMG}-v_{ANG})(1+\alpha_{AMG}-\beta_{ANG})B-\tau(X)\}- \\ \{(1+u_{BMG}-v_{BNG})(1+\alpha_{BMG}-\beta_{BNG})B-\tau(X)\}\end{vmatrix}\right] \tag{28}$$

For instance, let $x_{ij}^{k} = [S_2, S_3], (0.15,\ 0.25), (0.55,\ 0.60)$ and $x_{ij}^{q} = [S_1, S_2], (0.10,\ 0.15), (0.70,\ 0.75)$. Then, $d\left(x_{ij}^{k},\ x_{ij}^{q}\right) = \frac{1}{4(2-1)}[0.8075 + 0.76] = 0.3919$ and $Sup\left(x_{ij}^{k},\ x_{ij}^{q}\right) = 1 - d\left(x_{ij}^{k},\ x_{ij}^{q}\right) = 1 - 0.3919 = 0.6081$

Next, the values of $T\left(x_{ij}^{k}\right) = \sum_{j=1}^{n} Sup\left(x_{ij}^{k},\ x_{ij}^{q}\right)$ are obtained. In continuation with the above example, let $x_{ij}^{r} = [S_0, S_1], (0.00,\ 0.10), (0.85,\ 0.90)$ be the third LDULN. Then, $Sup\left(x_{ij}^{k},\ x_{ij}^{q}\right) = 0.6081$, $Sup\left(x_{ij}^{q},\ x_{ij}^{r}\right) = 0.5369$ and $Sup\left(x_{ij}^{k},\ x_{ij}^{r}\right) = 0.1450$. Then, $T\left(x_{ij}^{k}\right) = 0.6081 + 0.1450 = 0.7531$, $T\left(x_{ij}^{q}\right) = 0.6081 + 0.5369 = 1.1450$ and $T\left(x_{ij}^{r}\right) = 0.5369 + 0.1450 = 0.6819$

In Step 3 of the second stage of the proposed framework, the converted matrices from the experts are aggregated using the LDULPEWG operator as depicted in Equation (29):

$$\text{LDULFPEWG}\ (L_{LD-1},\ L_{LD-2},\ \ldots,\ L_{LD-n}) = \otimes_{\varepsilon_{i=1}^{n}} (L_{LD-i})^{w_i(1+(L_{LD-i}))/\sum_{i=1}^{n} w_i(1+(L_{LD-i}))} \tag{29}$$

where $T(L_{LD-i}) = \sum_{\substack{j=1 \\ j \neq i}}^{n} \sup(L_{LD-i},\ L_{LD-j})$ and sup $(L_{LD-i},\ L_{LD-j})$ is support for L_{LD-i} *from* L_{LD-j} and $u = (u_1, u_2, \ldots\ldots\ldots\ldots, u_n)^T$ is known as the weighting vector of the $(L_{LD-1}, L_{LD-2}, \ldots\ldots\ldots\ldots, L_{LD-n})$, such that $u_i \in [0, 1]$, $\sum_{i=1}^{n} u_i = 1$.

Here, the following algebraic equations are adopted:

$$L_{LD}^{\Phi} = \left(\begin{array}{c}\left[r_{L-\varnothing(Y)^{\Phi}},\ r_{L-\theta(Y)^{\Phi}}\right], \\ \left(\frac{2U_{LMG}(y))^{\Phi}}{(2-U_{LMG}(y))^{\Phi}+(U_{LMG}(y))^{\Phi}}, \frac{(1+V_{LNG}(y))^{\Phi}-(1-V_{LNG}(y))^{\Phi}}{(1+V_{LNG}(y))^{\Phi}+(1-V_{LNG}(y))^{\Phi}}\right), \\ \left(\frac{2(\gamma_{LMG})^{\Phi}}{(2-\gamma_{LMG})^{\Phi}+(\gamma_{LMG})^{\Phi}}, \frac{(1+\delta_{LNG})^{\Phi}-(1-\delta_{LNG})^{\Phi}}{(1+\delta_{LNG})^{\Phi}+(1-\delta_{LNG})^{\Phi}}\right)\end{array}\right) \tag{30}$$

$$L_{LD} \otimes M_{LD} = \left(\begin{array}{c}\left[r_{L-\varnothing(Y)+M-\theta(Y)},\ r_{L-\theta(Y)+M-\theta(Y)}\right], \\ \left(\frac{u_{LMG}(y)+u_{MMG}(y)}{1+(u_{LMG}(y)).(u_{MMG}(y))}, \frac{v_{LNG(y)}.v_{MNG}(y)}{1+(1-v_{LNG(y)}).(1-v_{MNG}(y))}\right), \\ \left(\frac{\gamma_{LMG}+\gamma_{MMG}}{1+(\gamma_{LMG}).(\gamma_{MMG})}, \frac{\delta_{LNG}.\delta_{MNG}}{1+(1-\delta_{LNG}).(1-\delta_{MNG})}\right)\end{array}\right) \tag{31}$$

In continuation with the ongoing example, the weighted aggregated result for the considered LDULNs is $[S_{3.48}, S_{4.11}], (0.9655,\ 0.0001), (1.6428,\ 0.0060)$.

The third stage of the framework is the ranking stage wherein the considered alternatives are evaluated with due consideration to the considered performance measures. This stage comprises four steps. In Step 1 of the third stage of the framework, the score values and/or the AVs are derived using Equations (33) and (34):

$$E_{L_{LD}} = r_{((L-\delta(Y)+L-(Y))\times t\left(\frac{1}{2}\right)n(u_{LMG}(y)+1-v(y)+(\delta+\gamma)))/4} \tag{33}$$

The AV is expressed by:

$$\xi_{L_{LD}} = \xi\ (L_{LD}) = r_{((U(a_1)+V(a_1))\times\left(\frac{1}{2}\right)(u_{LMG}(y)+v_{ANG}(y)q+h(\delta+\gamma))/4} \tag{34}$$

For instance, the score value for the obtained aggregated result is: $S_{3.98}$

The score values or the AVs are then used to arrive at the criteria weights (w_c) in Step 2 through any of the available weighting techniques. Once the criteria weights have been calculated, Equation (1) is used to obtain the relative criteria weights (w_{cr}) (Step 3). Step 4 of the third stage involves the calculation of the degree of dominance using Equation (3). For the degree of dominance, the score values are used to compare two LDULNs. If the score values do not reveal the order of the two LDULNs, then an AV, depicted in Equation (34), can be employed to arrive at the results of the comparative analysis. Subsequently, the ODS is obtained using Equation (4) through Step 5 of the third stage of the framework. Once the ODSs have been obtained, the rankings of the considered alternatives are obtained in Step 6, with the best-ranked having the highest ODS and the worst-performing of all having the lowest ODS.

3 Case study

The present case study relates to the identification of the best possible microgrid scenario for rural electrification in a village located in the north-east region of India. Providing a reliable and profitable operation of the microgrid to the customer is of utmost priority and this can be achieved through the incorporation of an optimized combination of renewable and conventional sources of energy. In the present case, the possible combinations of the available technologies are used as tabulated in Table 1. Fig. 2 depicts the general schema of the microgrid scenario MG_3 and the corresponding HOMER model has been shown in Fig. 3. In Fig. 3, Gen10 represents the FC, EO10 shows the WT, the converter is represented by 'Converter', CS6X-325P shows the PV panel and SAGM 06 2020 reflects the battery.

3.1 Mathematical modelling of the various microgrid components

The following discussion focuses on the mathematical modelling of various subsystems for the microgrid system.

3.1.1 *Model for PV panels*

Equation (35) depicts the power output of a PV panel as a function of time [45]:

Table 1: List of microgrid scenarios

Microgrid scenario code	Microgrid scenario composition
MG_1	PV–WT–battery converter
MG_2	PV–WT–DiG–battery converter
MG_3	PV–WT–FC–battery converter
MG_4	PV–FC–battery converter
MG_5	WT–FC–battery converter
MG_6	PV–DiG–battery converter
MG_7	WT–DiG–battery converter

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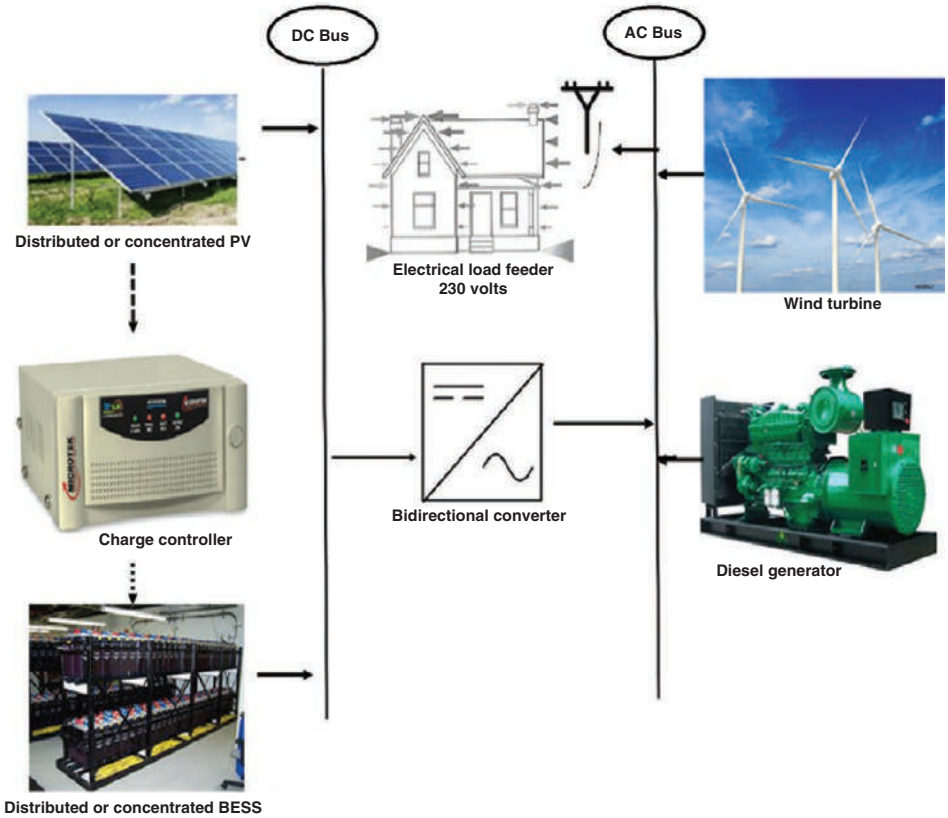

Fig. 2: General schematic diagram for the proposed HREM system

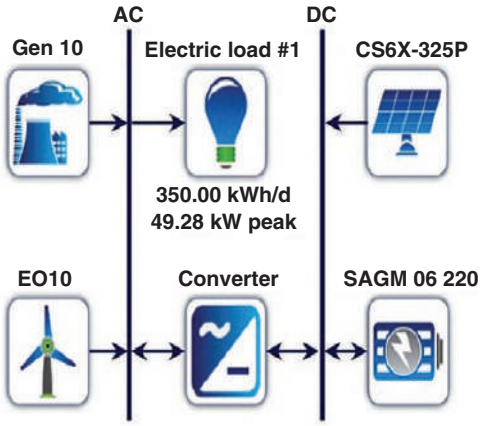

Fig. 3: Corresponding HOMER model (image from HOMER Pro modelling software used with permission from UL Solutions)

$$P_{PV}(t) = P_{PV,r}.f_{PV}.\left(\frac{G_T(t)}{G_{T,STC}}\right).\left[1 + C_p\left(T_{cell}(t) - 25\right)\right] \tag{35}$$

where the rated capacity for the PV array is represented by $P_{PV.r}$ (kW); f_{PV} reflects the derating factor associated with the PV panel, G_T and $G_{T,STC}$ (kW/m^2) represent the solar radiation on the PV under the real and standard conditions, respectively; C_p (%/°C) represents the power temperature coefficient; and T_{cell} (°C) represents the real-time temperature of the PV panel. The real-time temperature of the PV system can be determined using Equation (36) [45, 46]:

$$T_{cell}(t) = T_\alpha(t) + \left(T_{cell,NOCT} - T_{\alpha,NOCT}\right).\left(\frac{G_T(t)}{G_{T,NOCT}}\right).\left[1 - \frac{\eta_c}{\alpha.\tau}\right] \tag{36}$$

where T_α (°C) denotes the ambient temperature; the normal operating temperature of the PV is represented by $T_{cell,NOCT}$ (°C), the ambient temperature when $T_{cell,NOCT}$ has been determined; the electrical conversion efficiency of the PV is denoted by η_c (%); the transmittance of the shield that is located above the PV surface is represented by τ; and the solar absorption by the PV is represented by α.

3.1.2 Model for FC

In the present case, the proton exchange membrane type of FC is modelled emulating the natural-gas-fired generator [45, 47]. Equation (37) provides the formulation to arrive at the consumption rate of natural gas by the FC:

$$F_{FC}(t) = a_{FC}.P_{FC,g}(t) + b_{FC}.P_{FC,r} \tag{37}$$

where the rate of consumption of natural gas by the FC is denoted with $F_{FC}(t)$ (L/h), the output power is represented by $P_{FC,g}$ (kW) and the rated capacity of the FC is given by $P_{FC,r}$ (kW). The fuel intercept coefficient is denoted with a_{FC} (L/hr/kW$_{rated}$) and the slope of the natural-gas curve is represented by b_{FC} (L/hr/kW$_{output}$).

3.1.3 Model for power converter

The sizes of batteries and the RESs are the determinant factors for deciding the optimal sizing of the power converter. The power that would be released in either direction plays a dominant role in deciding the size of the power converter that is required to be installed. The size of the power converter should be more than the power released. The following relations can be used to arrive at the energy-conversion efficiencies of the power converter from DC to AC ($\eta^{Con}_{DC/AC}$) and AC to DC ($\eta^{Con}_{AC/DC}$).

$$\eta^{Con}_{DC/AC}.\left[P_{BAT}(t) + P_{PV}(t) + P_{FC}(t)\right] \le N_{conv} \tag{38}$$

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$$\eta_{AC/DC}^{Con} \cdot [P_{WT}(t) + P_{DiG}(t)] \leq N_{conv} \tag{39}$$

3.1.4 Model for WT

Equation (40) can be used to determine the wind speed [45]:

$$v_w(t) = v_{anem}(t) \cdot \left[\frac{ln\left(\frac{H_{hub}}{H_0}\right)}{ln\left(\frac{H_{anem}}{H_0}\right)} \right] \tag{40}$$

where the wind speeds at the anemometer and hub heights are denoted by $v_w(t)$ and $v_{anem}(t)$ (m/sec). The surface roughness length is represented by H_0 (m), the hub height is denoted by H_{hub} (m) and the anemometer height is expressed as H_{anem} (m).

Equation (41) can be used to obtain the WT power output under the standard operating conditions of temperature and pressure [45, 48]:

$$P_{w,STP}(t) = \begin{cases} 0 & v_w(t) < v_i \\ P_{w,r} \cdot \left[\frac{v_w^3(t) - v_i^3}{v_n^3 - v_i^3} \right] & v_i \leq v_w(t) \leq v_n \\ P_{w,r} & v_n \leq v_w(t) \leq v_0 \\ 0 & v_w(t) > v_0 \end{cases} \tag{41}$$

where the rated power output is denoted with $P_{w,r}$, the power output under standard conditions for temperature and pressure is expressed as $P_{w,STP}$ and the cut-out, cut-in and rated speeds are denoted by v_0, v_i and v_r.

The computed values can be adjusted to the actual conditions using the following formulation [45]:

$$P_w(t) = P_{w,STP}(t) \cdot \left(\frac{\rho(t)}{\rho_0} \right) \tag{42}$$

The actual density of the air is represented as ρ (kg/m^3) and the density of the air under standard conditions is expressed as ρ_0 (1.225 kg/m^3).

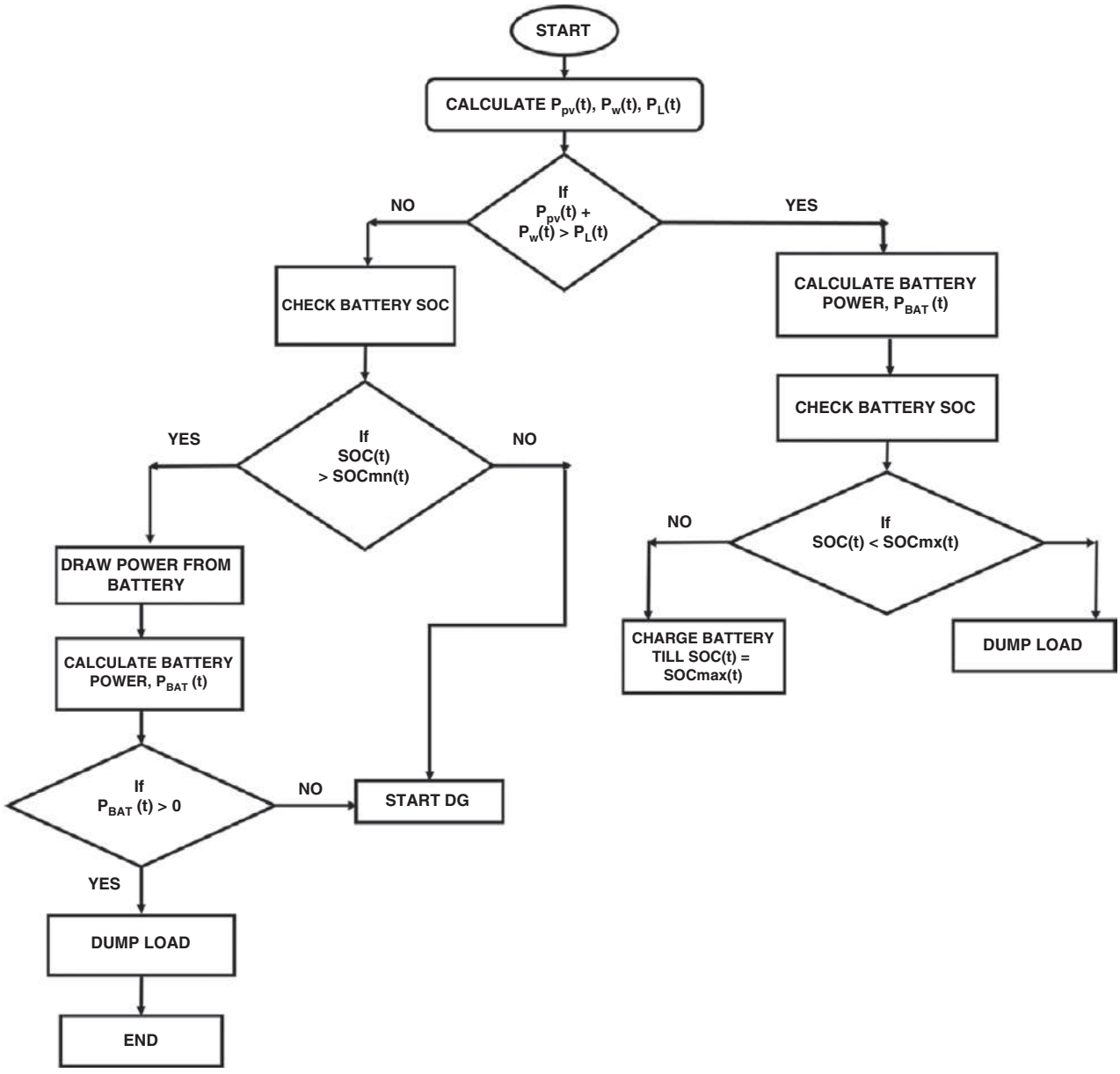

Fig. 4: Operational strategy for the PV–WT–FC–battery converter HREM system

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3.1.5 Model for diesel generator

The reliability of the microgrid system can be ensured by integrating it with the diesel generator. Equation (43) can be used to arrive at the output power of a diesel generator [45]:

$$F_{DiG}(t) = a_{DiG}.P_{DiG,g}(t) + b_{DiG}.P_{DiG,r} \tag{43}$$

where $F_{DiG}(t)$ (L/h) reflects the rate of consumption of fuel by the DiG, the output power is represented by $P_{DiG,g}(t)$ (kW) and the rated capacity of the diesel generator is given by $P_{DiG,r}$ (kW). The fuel intercept coefficient is denoted with a_{DiG} (L/hr/kW$_{rated}$) and the slope of the natural-gas curve is represented by b_{DiG} (L/hr/kW$_{output}$).

3.1.6 Model for battery

The capacity of the battery to be used as an energy-storage system within the microgrid system can be obtained using Equation (44) [45, 49]:

$$C_{wh}^{BAT}(t) = \left[\frac{E_{load}(t).DA(t)}{\eta_{Conv}.\eta_{BAT}.\ DoD\ (t)}\right] \tag{44}$$

where the average energy demand is denoted by E_{load} (kWh/day), days of autonomy are represented by DA, DoD represents the depth of the discharge of the used battery and the efficiencies of the battery and converter are denoted by η_{BAT} and η_{Conv}, respectively.

The state of charge of the battery can be obtained using Equation (45):

$$SOC(t) = SOC(t - \Delta t) - \frac{P_{BAT}(t).\Delta t}{E_{nom}} \tag{45}$$

Equation (46) represents the energy available in the battery at any given time t:

$$E_{BAT}(t) = E_{BAT}(t - \Delta t) - P_{BAT}(t).\Delta t \tag{46}$$

where the nominal capacity of the battery is denoted by E_{nom} and the power exchanged at any time t is represented by $P_{BAT}(t)$.

The following constraint governs the charging and discharging operation of the battery:

$$P_{max,c}^{BAT}(t) \le P_{BAT}(t) \le P_{max,d}^{BAT}(t) \tag{47}$$

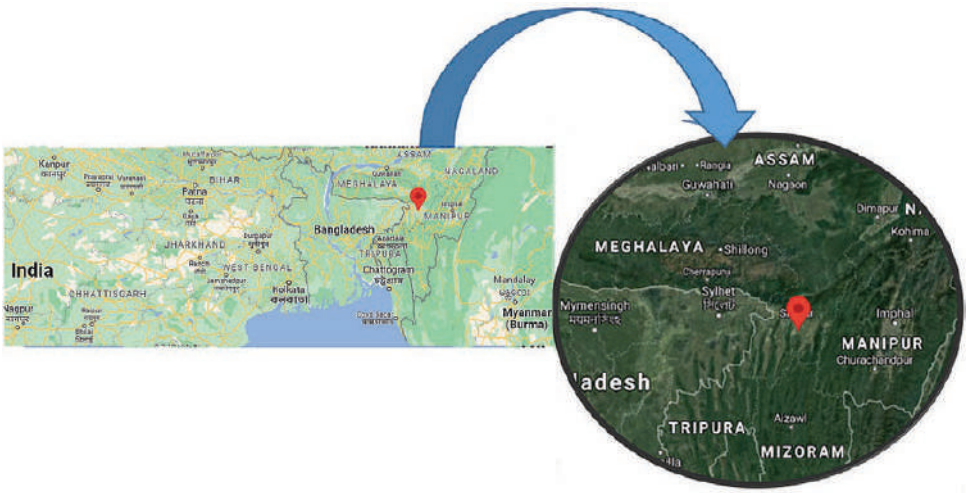

Fig. 5: Geographical view of the study area of Silchar Assam, India [52]

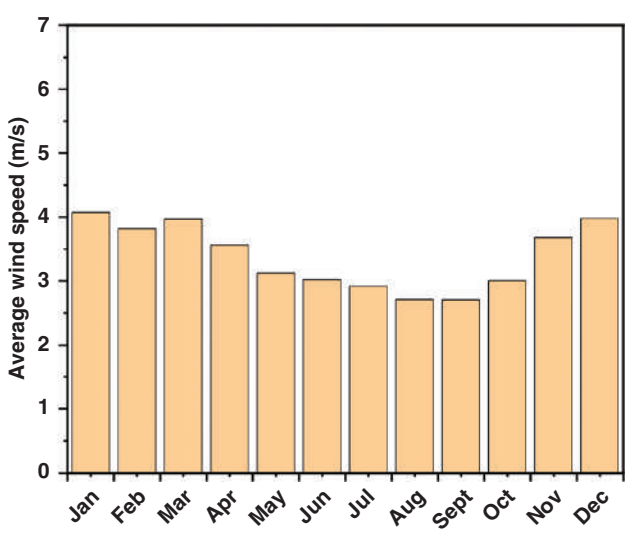

Fig. 6: Monthly average wind profile for the proposed HREM system

Table 2: Main criteria and subcriteria for evaluating the considered microgrid scenarios

Criteria	No.	Subcriteria
Economic criteria	C_1	Levelized cost of energy (LCOE)
	C_2	Annualized system cost (ASC)
	C_3	Total fuel cost
	C_4	Total capital cost
Technical criteria	C_5	Total electricity production
	C_6	Battery losses
	C_7	Excess electricity
	C_8	Generator capacity factor
Environmental criteria	C_9	Renewable fraction
	C_{10}	Fuel consumption
	C_{11}	CO_2 discharge
	C_{12}	Other discharges
Social criteria	C_{13}	New jobs
	C_{14}	Benefits to public health
	C_{15}	Sociocultural awareness
	C_{16}	Local resources

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Table 3: Expert decision matrix

		MG_1	MG_2	MG_3	MG_4	MG_5	MG_6	MG_7
C_1	E_1	OL	VL	VL	VL	L	OL	H
	E_2	L	VL	VL	VL	L	O	OH
	E_3	OL	VL	VL	VL	L	OL	OH
C_2	E_1	VL	OH	L	H	H	VH	VVH
	E_2	VL	H	L	H	H	H	VVH
	E_3	VVL	OH	VL	H	H	VH	VH
C_3	E_1	H	VH	VH	OH	OL	OL	L
	E_2	H	VVH	VH	H	O	O	OL
	E_3	H	VVH	VH	O	OL	O	L
C_4	E_1	VVL	OL	L	OL	O	OH	OH
	E_2	VL	OL	L	OL	OH	H	H
	E_3	VL	O	L	O	OH	H	H
C_5	E_1	H	VH	VVH	O	L	O	VL
	E_2	OH	H	VH	OH	L	OH	VL
	E_3	H	VH	VH	OH	OL	OH	L

The maximum discharge and charge power of the battery at any time t is expressed by $P^{BAT}_{max,d}(t)$ and $P^{BAT}_{max,c}(t)$, respectively.

3.1.7 *Model for air pollution*

The operation of the FC, diesel generator and boiler produces carbon emissions and hence adversely affects the environment. Therefore, it becomes quintessential to adjudge the environmental performance of the scenarios considered. This has been achieved by correlating this with the rate of fuel consumption [50]:

$$TCE_{comp} = 3.667.m_f.LHV_{fuel}.CEF_f.X_c \tag{48}$$

where the total amount of carbon dioxide emissions by a component is denoted by TCE; m_f (L) represents the amount of fuel that gets consumed; LHV_{fuel} (MJ/L) denotes the lower heating value; the carbon emission factor is denoted by CEF_f (ton carbon/TJ); and the oxidized faction of emitted carbon is represented by X_c.

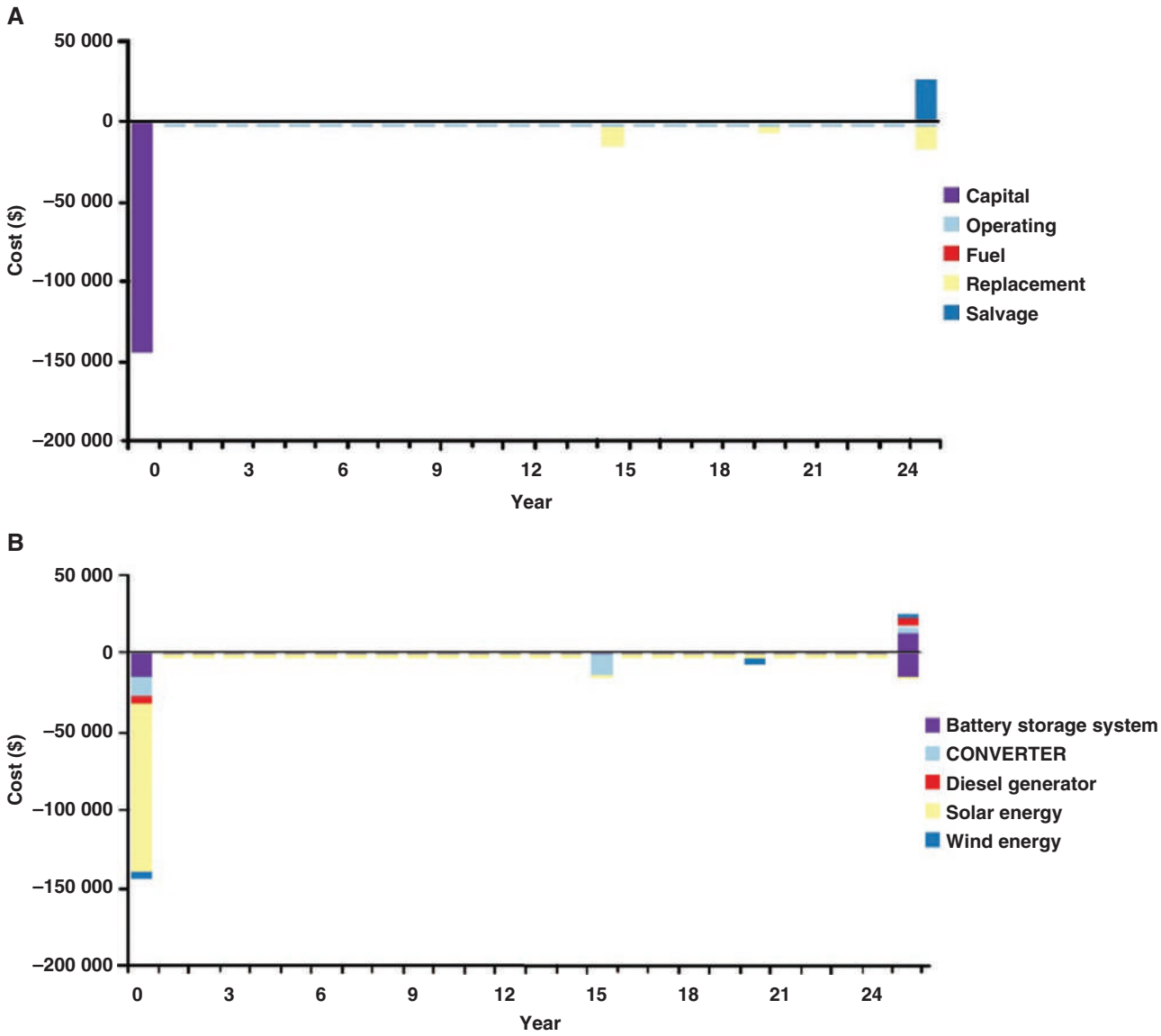

Fig. 7: Annual cash flow of PV–WT–FC–battery converter microgrid system (image from HOMER Pro modelling software used with permission from UL Solutions)

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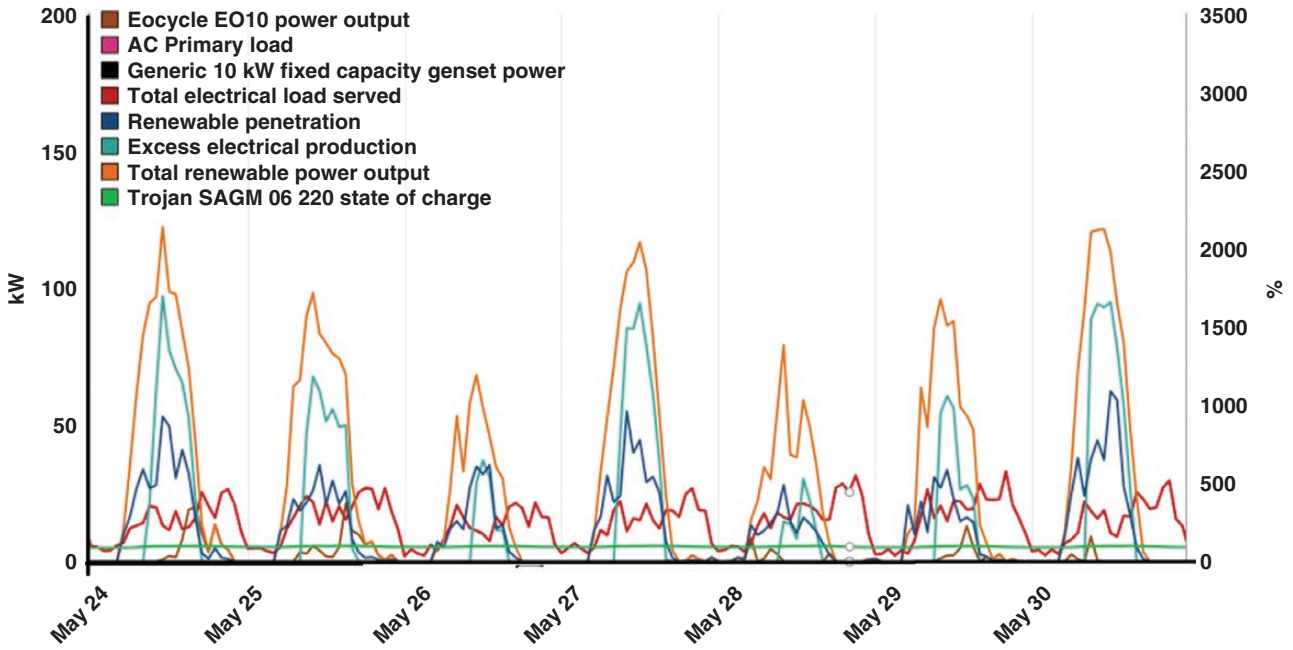

Fig. 8: Scheduling of electrical power consumption and generation for PV–WT–FC–battery converter microgrid system (1 week of May) (image from HOMER Pro modelling software used with permission from UL Solutions)

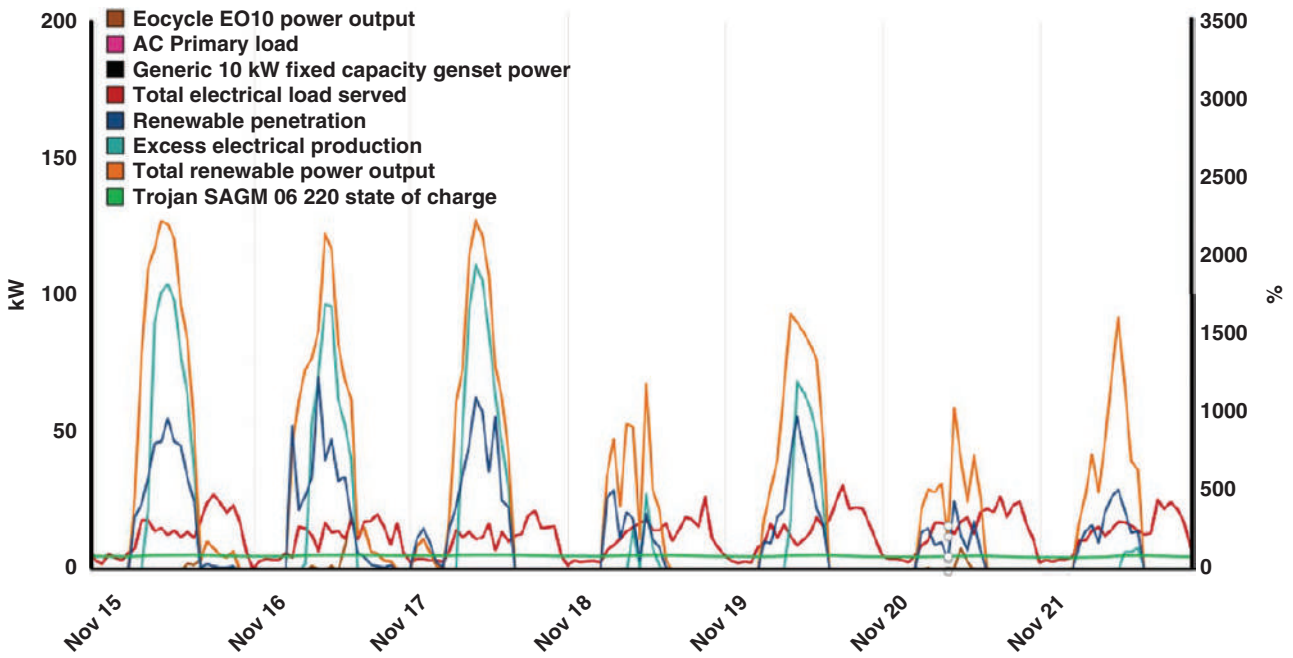

Fig. 9: Scheduling of electrical power consumption and generation for the PV–WT–FC–battery converter microgrid system (1 week of November) (image from HOMER Pro modelling software used with permission from UL Solutions)

3.2 Objective function

The financial merit of the different scenarios has been obtained through the outcome of the annualized system cost (ASC) and the levelized cost of energy (LCOE) taking into account the constraints associated with the different microgrid subsystems [50]:

$$\textit{Objective function} = \textit{minimize}\ \ (ASC) = \sum_{comp\ \in\ PV,\ WT,\ FC,\ \ DiG,\ \ BAT,\ CONV} [N_{comp} C_{comp}]$$

Here, the number of components is expressed by N_{comp}. The cost for each of the microgrid subsystems comprises the following components: capital and installment cost (C_{acp}), replacement cost (C_{rp}), operational cost (C_{ac}), salvage cost (C_{slvg}), and annual maintenance cost (C_{am}).

Equation (49) can be used to arrive at the LCOE for the microgrid scenario:

$$LCOE = \frac{ASC \times DF(i, n_{proj})}{\sum E_{gen}(t)} \tag{49}$$

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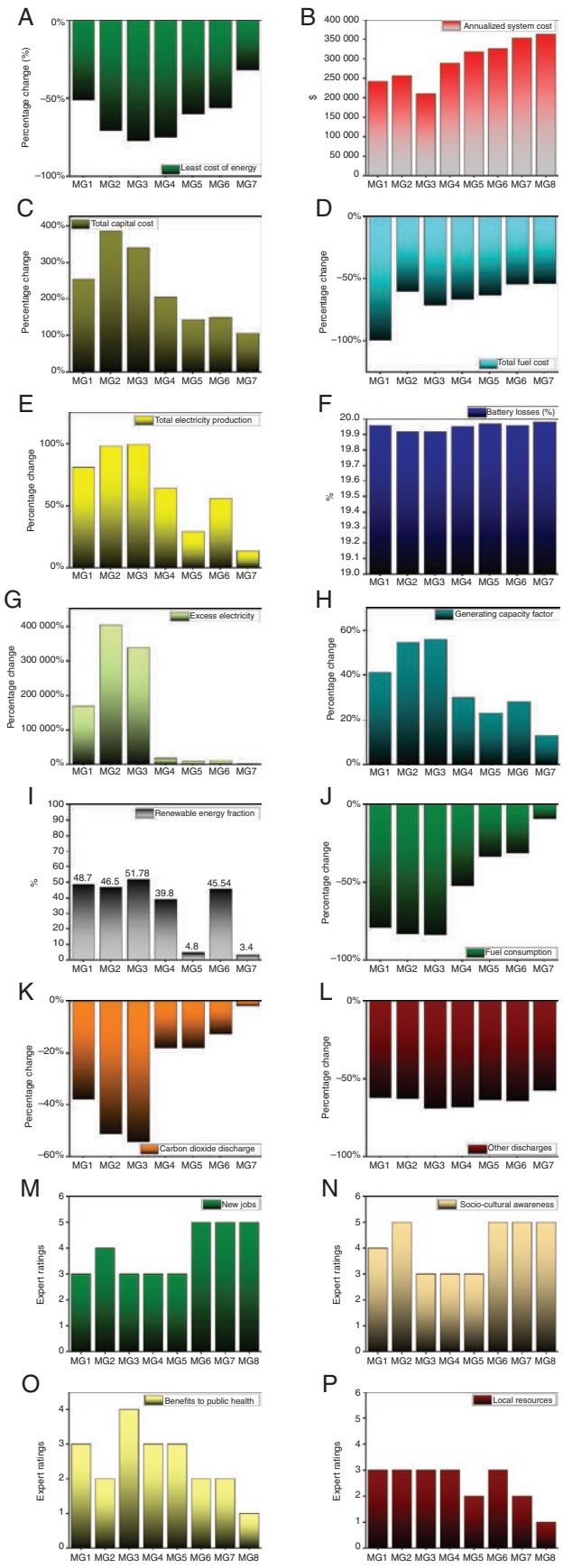

Fig. 10: Comparative analysis of microgrid scenarios for various performance metrics concerning the base scenario (DiG only)

Fig. 11: The conversion scale

The discounting factor is denoted as CRF(i,n_{proj}) and can be determined using the following:

$$CRF\,(i, n_{proj}) = \frac{i.(1+i)^{n_{proj}}}{[(1+i)^{n_{proj}} - 1]} \tag{50}$$

The renewable-energy fraction, which signifies the amount of energy delivered by RESs within the microgrid scenario, can be obtained using Equation (51):

$$RF = 1 - \left[\frac{E_g^{nren} + H_g^{nren}}{(E_{load} + H_{load})}\right] \tag{51}$$

where the total generation of electricity and the heat from the non-renewable sources of energy are denoted by E_g^{nren} and H_g^{nren} (kWh/yr).

3.3 Operational strategy

The objective of the operational strategy for the hybrid microgrid system is to meet the load requirement of the area, taking into account the reliability factor, economic aspects and environmental impacts. The present research work considers optimizing the utilization of renewable resources. Therefore, FCs and diesel generators are only operated when there is a load shortage from RESs. Moreover, these can be used only to charge the battery and therefore the fuel consumption can be reduced. The adopted operational strategy is depicted in Fig. 4.

3.4 Study area

The present case relates to the remote village located in the southern region of the north-eastern state of Assam, India. The location has been depicted in Fig. 5. The estimated thermal and electrical load can be accessed from Singh *et al.* [50]. Renewable-energy data have been sourced from NASA's surface metrology and solar energy database [51]. The monthly average hourly global solar radiation for the remote village considered can be accessed from Singh *et al.* [50]. Fig. 6 depicts the average wind-speed profile.

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Table 4: The LDULNs matrix

		MG_1	MG_2	MG_3	MG_4	...	MG_7
C_1	E_1	[{S3, S4} (0.30, 0.40), (0.45, 0.50)]	[{S1, S2} (0.10, 0.15), (0.70, 0.75)]	[{S1, S2} (0.10, 0.15), (0.70, 0.75)]	[{S1, S2} (0.10, 0.15), (0.70, 0.75)]	...	[{S4, S5} (0.60, 0.70), (0.20, 0.25)]
	E_2	[{S2, S3} (0.15, 0.25), (0.55, 0.60)]	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S1, S2} (0.10, 0.15), (0.70, 0.75)]	...	[{S3, S4} (0.50, 0.60), (0.25, 0.30)]
	E_3	[{S3, S4} (0.30, 0.40), (0.45, 0.50)]	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S1, S2} (0.10, 0.15), (0.70, 0.75)]	...	[{S3, S4} (0.50, 0.60), (0.25, 0.30)]
C_2	E_1	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S3, S4} (0.50, 0.60), (0.25, 0.30)]	[{S2, S3} (0.15, 0.25), (0.55, 0.60)]	[{S4, S5} (0.60, 0.70), (0.20, 0.25)]	...	[{S5, S6} (0.80, 0.90), (0.05, 0.10)]
	E_2	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S4, S5} (0.60, 0.70), (0.20, 0.25)]	[{S2, S3} (0.15, 0.25), (0.55, 0.60)]	[{S4, S5} (0.60, 0.70), (0.20, 0.25)]	...	[{S5, S6} (0.80, 0.90), (0.05, 0.10)]
	E_3	[{S0, S1} (0.00, 0.10), (0.85, 0.90)]	[{S3, S4} (0.50, 0.60), (0.25, 0.30)]	[{S1, S2}(0.10, 0.15), (0.70, 0.75)]	[{S4, S5} (0.60, 0.70), (0.20, 0.25)]	...	[{S5, S6} (0.70, 0.80), (0.15, 0.20)]

Table 5: The LDULNs matrix

	C_1	C_2	C_3	C_4
MG_1	[{$S_{3.9499}$, $S_{4.4638}$} (0.9806, 0.0003), (1.2818, 0.0032)]	[{$S_{3.2323}$, $S_{3.9412}$} (0.9590, 0.0001), (1.7174, 0.0087)]	[{$S_{4.4820}$, $S_{5.0419}$} (0.9987, 0.0042), (0.9500, 0.0002)]	[{$S_{2.2323}$, $S_{3.6979}$} (0.8588, 0.0000), (1.9355, 0.0137)]
MG_2	[{$S_{3.2323}$, $S_{3.9412}$} (0.9590, 0.0001), (1.7174, 0.0087)]	[{$S_{4.3484}$, $S_{7.948}$} (0.9964, 0.0018), (0.9982, 0.0006)]	[{$S_{4.7469}$, $S_{5.1396}$} (0.9991, 0.0055), (0.9922, 0.0001)]	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]
MG_3	[{$S_{3.2323}$, $S_{3.9412}$} (0.9590, 0.0001), (1.7174, 0.0087)]	[{$S_{3.7810}$, $S_{4.3303}$} (0.9710, 0.0002), (1.3618, 0.0041)]	[{$S_{4.7469}$, $S_{5.1396}$} (0.9991, 0.0055), (0.9922, 0.0001)]	[{$S_{3.7810}$, $S_{4.3303}$} (0.9710, 0.0002), (1.3618, 0.0041)]
MG_4	[{$S_{3.2323}$, $S_{3.9412}$} (0.9590, 0.0001), (1.7174, 0.0087)]	[{$S_{4.4820}$, $S_{5.0419}$} (0.9987, 0.0042), (0.9500, 0.0002)]	[{$S_{4.3484}$, $S_{7.948}$} (0.9964, 0.0018), (0.9982, 0.0006)]	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]
MG_5	[{$S_{3.7810}$, $S_{4.3303}$} (0.9710, 0.0002), (1.3618, 0.0041)]	[{$S_{4.4820}$, $S_{5.0419}$} (0.9987, 0.0042), (0.9500, 0.0002)]	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]
MG_6	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]	[{$S_{4.5943}$, $S_{5.0048}$} (0.9980, 0.0030), (0.9998, 0.0004)]	[{$S_{4.1701}$, $S_{4.6422}$} (0.9871, 0.0005), (1.2038, 0.0025)]	[{$S_{4.3484}$, $S_{7.948}$} (0.9964, 0.0018), (0.9982, 0.0006)]
MG_7	[{S_{3036}, $S_{4.7545}$} (0.9964, 0.0018), (1.0101, 0.0006)]	[{$S_{4.7469}$, $S_{5.1396}$} (0.9994, 0.0076), (1.1326, 0.0001)]	[{$S_{4.0011}$, $S_{4.5086}$} (0.9807, 0.0003), (1.2592, 0.0032)]	[{$S_{4.3484}$, $S_{7.948}$} (0.9964, 0.0018), (0.9982, 0.0006)]

3.5 Application of the proposed decision-making methodology

Following the proposed decision-making approach, the feasible set of alternatives and criteria is identified during the initialization stage. In the present case study, the microgrid scenarios based on hybrid renewable energy considered form the set of alternatives. The set of criteria encompasses the techno–enviro–economic–social metrics. The considered criteria are summarized in Table 2. The evaluations were provided by three domains and the associated weight vector has been taken as $\{w^k = (0.33,\ 0.34,\ 0.33)^T\}$.

The evaluations are provided based on the results associated with the techno-economic analysis of the considered HREM systems. For Expert 1, the linguistic evaluations have been tabulated in Table 3. Only a few criteria have been shown for illustrative purposes. Techno-environmental results have been obtained using HOMER [53]. The cash-flow diagram for the PV–WT–FC–battery converter (MG_3) has been depicted in Fig. 7. Power consumption and generation for 1 week of May and November are shown in Figs 8 and 9, respectively. Social consideration considers the creation of new jobs, benefits associated with public health, sociocultural awareness and local resources. The results obtained for the considered scenarios have been delineated comparatively in Fig. 10.

According to the second stage of the proposed framework relating to aggregation, the preferences obtained from different experts are aggregated through Steps (1)–(4). In this pursuit, the obtained evaluations are converted to LDULNs following the scale depicted in Fig. 11. The converted matrix is shown in Table 4. To maintain the conciseness of the article, only a few criteria have been shown in Table 4. The aggregated decision matrix is then obtained through Steps (2)–(4) using the LDULPEWG operator and the same has been shown in Table 5.

As per the third phase, the ranking of the alternatives is processed through Steps (1)–(4). The score values have been shown in Table 6. The obtained values of the criteria and the relative weights of the criteria have been tabulated in Table 7.

4 Results

Fig. 12 shows the values for the dominance degree as well as the ODS for the alternatives considered. As per the tabulation, the following ranking order can be observed for the considered alternatives: $MG_3 > MG_4 > MG_2 > MG_5 > MG_7 > MG_1 > MG_6$.

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Table 6: Score values obtained for different alternatives

	MG_1	MG_2	MG_3	MG_4	MG_5	MG_6	MG_7
C1	6.87	6.61	6.61	6.61	6.77	6.86	6.81
C2	6.61	6.84	6.77	7.03	7.03	7.19	7.72
C3	7.01	7.38	7.40	6.84	6.86	6.86	6.90
C4	5.65	7.03	6.77	7.03	6.66	6.84	6.84
C5	6.81	7.19	7.48	6.66	6.77	6.66	6.61
C6	6.81	6.86	7.03	6.81	6.64	6.81	6.64
C7	7.03	7.38	7.19	6.90	5.71	2.82	4.62
C8	7.03	6.81	6.79	6.84	7.48	6.84	7.48
C9	6.81	7.21	7.40	6.81	6.77	6.81	6.63
C10	6.77	5.65	4.62	6.77	6.91	6.71	7.03
C11	6.77	6.61	4.62	6.81	6.81	7.03	7.21
C12	6.77	6.77	4.62	4.62	6.77	6.77	6.77
C13	7.03	7.40	7.03	7.03	7.03	7.40	7.40
C14	7.03	7.19	6.85	7.03	6.84	7.40	7.40
C15	7.03	6.66	7.40	7.21	7.21	6.66	6.66
C16	7.03	7.03	7.03	6.81	6.79	7.03	6.79

Table 7: Relative subcriteria weights

Criteria	No.	Subcriteria weights	Relative criteria weights
Economic criteria	C_1	0.0600	0.6097
	C_2	0.0728	0.8411
	C_3	0.0627	0.7549
	C_4	0.0938	1.0000
Technical criteria	C_5	0.0907	0.7202
	C_6	0.0621	0.5833
	C_7	0.0878	0.6191
	C_8	0.0912	0.6549
Environmental criteria	C_9	0.0913	0.6907
	C_{10}	0.0979	0.7265
	C_{11}	0.0985	0.7623
	C_{12}	0.0911	0.7982
Social criteria	C_{13}	0.0921	0.8340
	C_{14}	0.0930	0.8698
	C_{15}	0.0915	0.9056
	C_{16}	0.0934	0.9414

4.1 Test and validation

In the ensuing discussion, the accuracy and robustness of the obtained ranking results have been investigated. A sensitivity analysis has been carried out on the attenuation factor and the weights of the criteria. The ranking results have been validated by addressing other case studies from previous work. The comparison of the ranking results is then approached through the employability of the Spearman correlation coefficient. A value of the Spearman correlation coefficient of >0.8 depicts a very strong relationship between the rankings obtained.

4.1.1 *Sensitivity analysis: attenuation factor*

The classification orders of the different microgrid scenarios have been investigated for the different attenuation factors (θ), i.e. 0.1, 1, 2, 5, 10, 50 and 100. To accomplish the same, for each of the attenuation factor values, the dominance score has been determined. The results that have been obtained through the proposed approach with consideration of different values of attenuation factor are depicted in Fig. 13. From the depicted results obtained based on the ODS, it can be observed that the ranking results are more than stable for the following values of attenuation factors: 0.1, 1 and 2. However, for the higher values of θ, i.e. 5, 10, 50 and 100, certain variations in the performance assessment for the alternatives are apparent from the depiction. The variation in ranking results shows clearly the instrumental role that the attenuation factor plays in the deduced performance-appraisal results.

4.1.2 *Sensitivity analysis: criteria weights*

The stability of the ranking results has also been judged by analysing the changes in the weights of the criteria. This has been approached by changing the weights of the criteria by 20%, 40% and 60%, one at a time. The results obtained for the performance appraisal based on the first approach of the proposed methodology are presented in Fig. 14. This has been achieved for $\theta = 1$. Stability in ranking results about the distinct criteria weights can be observed from the depiction in Fig. 14.

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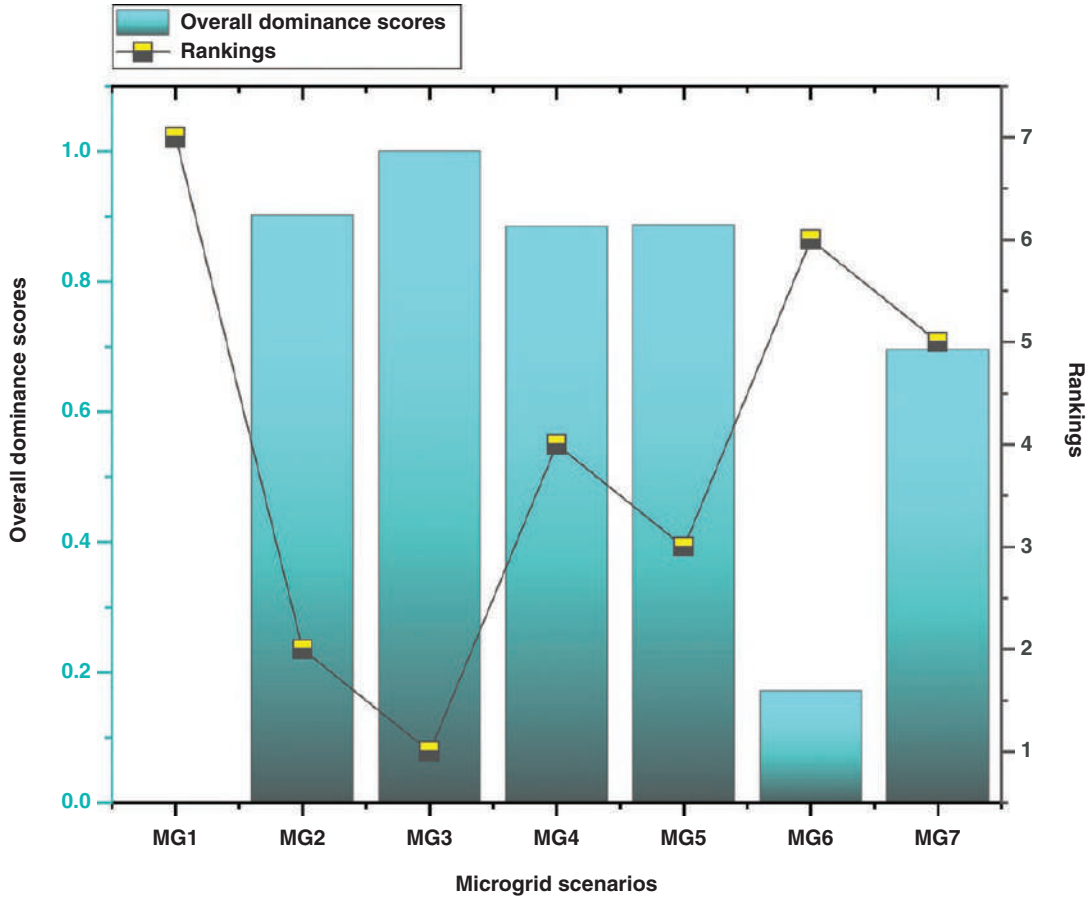

Fig. 12: Results of the performance analysis for different microgrid scenarios based on the overall dominance score

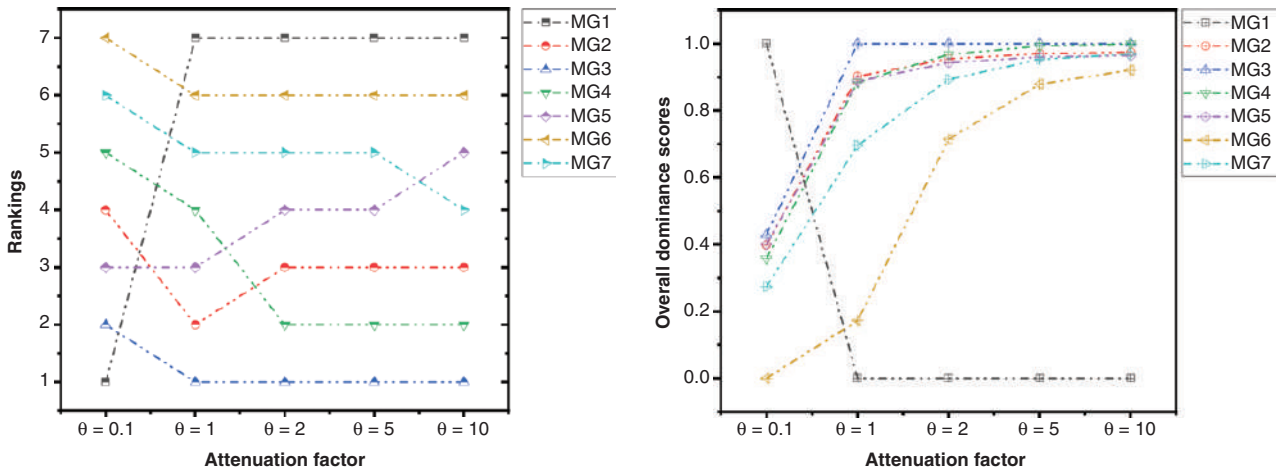

Fig. 13: Sensitivity analysis results taking into account different values of the attenuation factor

4.1.3 *Previous case studies solved using the proposed methodology*

The ranking results obtained through the presented performance-appraisal approach have been validated through previous case studies. The two illustrative examples that have been considered relate to the selection of optimal hydrogen energy-storage plants and the selection of an optimal renewable energy source.

4.1.3.1 *Illustrative Example I*

The illustrative example has been adopted from Gokasar *et al.* [54] relating to the classification of bridge maintenance projects taking into account CO_2 emissions. A total of five alternatives were evaluated under the influence of eight criteria. This was processed through the employability of type-2 neutrosophic number-based weighted aggregated sum product assessment and the technique for order preference by similarity to an ideal solution approach. The results obtained using the proposed approach are delineated in Fig. 15. The depiction shows the following ranking order: $P_4 > P_1 > P_5 > P_2 > P_3$. The following order of ranking results has been reported by Gokasar *et al.* [54] according to their adopted approach: $P_4 > P_2 > P_5 > P_1 > P_3$. The values of the Spearman correlation coefficient for the two ranking results have been obtained

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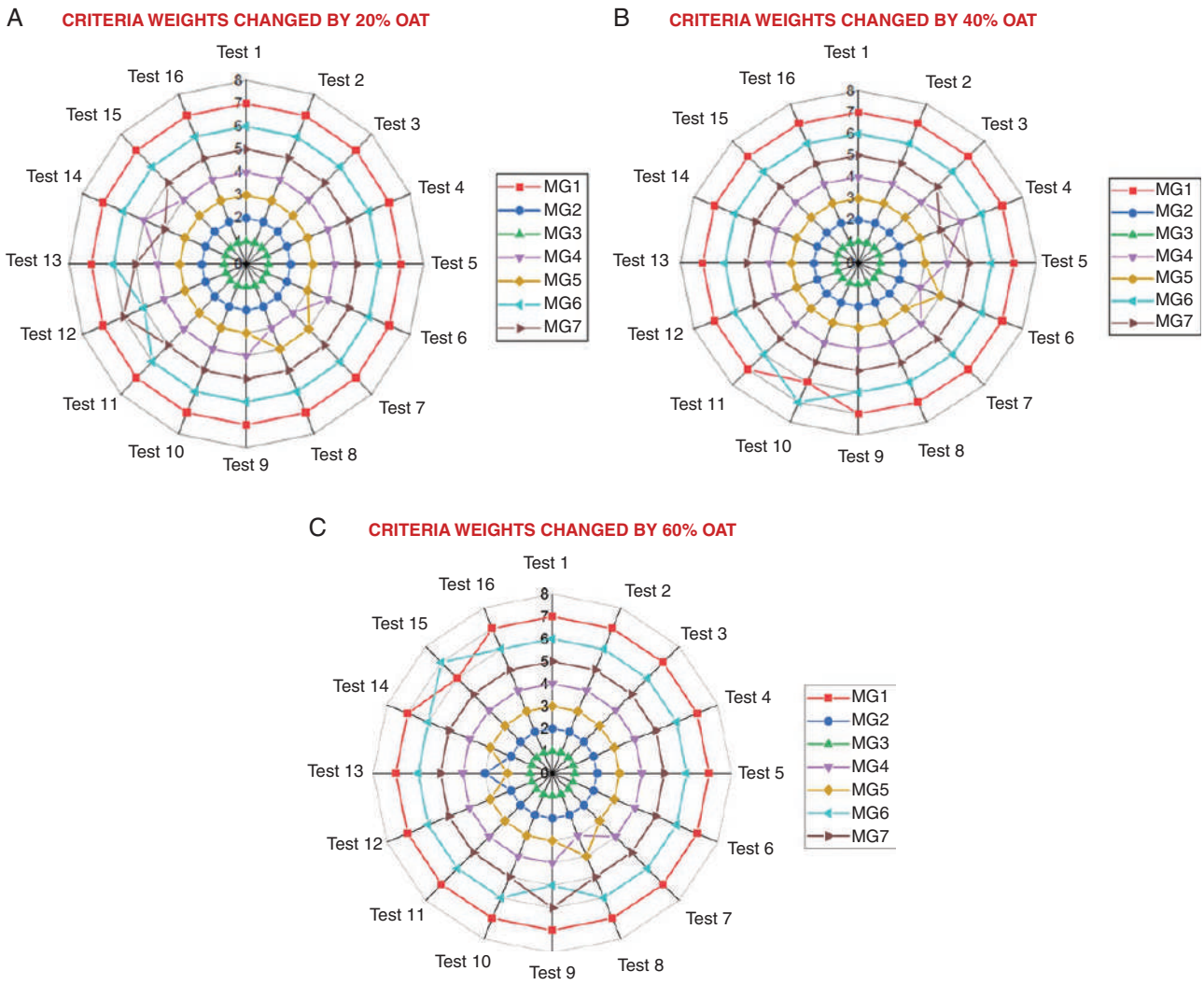

Fig. 14: Sensitivity analysis concerning the criteria weights based on one-at-a-time approach

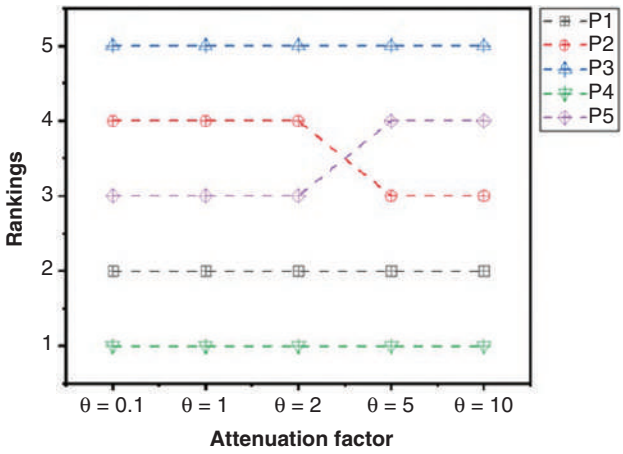

Fig. 15: Performance appraisal of different maintenance bridge projects based on the overall dominance score

as 0.9. Although variations in results have been observed, alternative P_4 has been revealed to be the best.

4.1.3.2 Illustrative Example II

The second previous case study has been taken from Krishankumar *et al.* [55] in which the problem associated with the selection of the best renewable energy source with due consideration to sustainability performance measures has been studied. The case study was solved for Karnataka, India using the q-rung orthopair fuzzy TODIM approach. Five renewable sources of energy were investigated with due consideration to the 14 subcriteria that were grouped under five main criteria. This case study was addressed using the presented approach, and the ranking results are depicted in Fig. 16. The following order of ranking was observed for the electric bus charging sites: $RS_2 > RS_5 > RS_3 > RS_1 > RS_4$. The order of ranking was for the attenuation factor, i.e. $\theta = 1$. The ranking order revealed in the study by Krishankumar *et al.* [55] exhibited the following order: $RS_2 > RS_4 > RS_3 > RS_1 > RS_5$. The Spearman correlation coefficient was 0.9.

5 Conclusions

Microgrids based on renewable energy resources are one of the solutions that can help achieve Goal 7 of the United Nations Sustainable Development Goal of 'Affordable and clean energy'. The sustainability benefits of microgrids can be effectively adjudged through the consideration of various sustainability performance measures that are certainly conflicting in nature. As such, opting for the best microgrid scenario becomes a challenging task for experts. Therefore, to address the challenge and to truly realize and achieve sustainable development goals, this work proposed a novel approach to decision-making that can aid

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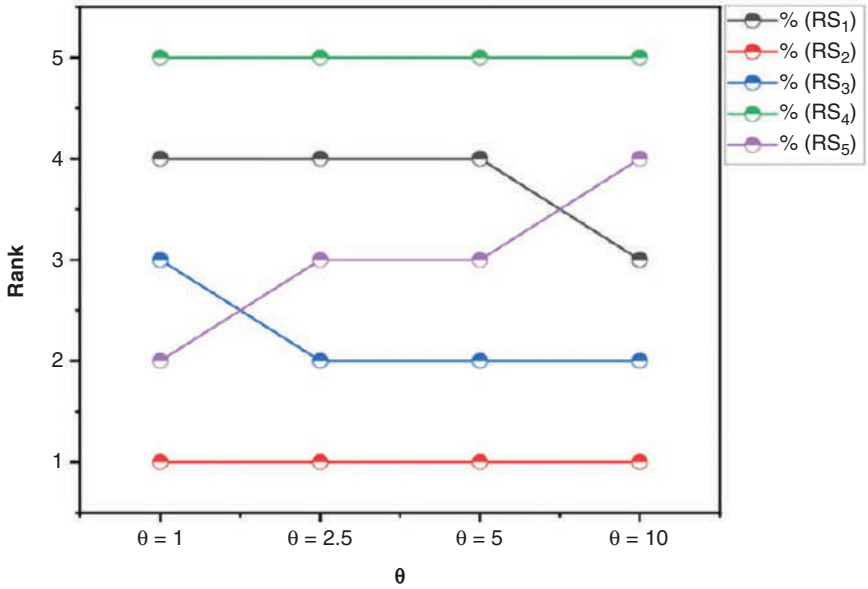

Fig. 16: Performance evaluation of different renewable energy sources based on the overall dominance score

the experts in opting for the best possible microgrid scenario for rural electrification. This has been achieved with due consideration to the various sustainability performance measures. A total of seven possible microgrid scenarios were evaluated for the electrification of a remote village in Assam, India using the proposed decision-making approach. The following summary describes the results obtained:

- Environmental criteria were attached with a maximum weight of 38% followed by social criteria wherein a weight of 37% was attached.
- From the economic point of view, the LCOE of a PV–WT–FC–battery converter (MG_3) was the lowest with respect to the considered microgrid scenarios considered. The ASC was best for the PV–WT–FC–battery converter (MG_3) scenario. The PV–WT–FC–battery converter (MG_3) had the lowest total capital cost. The lowest total fuel cost was revealed for the PV–WT–FC–battery converter (MG_3) scenario.
- In terms of environmental impact, the CO_2 discharge for the PV–WT–FC–battery converter (MG_3) scenario was the lowest of all possible microgrid scenarios.
- From the social parameter point of view, the PV–WT–FC–battery converter (MG_3) is better as far as the benefits of public health are concerned. Regarding job creation, the PV–WT–FC–battery converter (MG_3) was the best of all the scenarios considered. Sociocultural awareness was assayed to be better for the PV–WT–FC–battery converter (MG_3) scenario.
- The assessment score obtained based on the average ODS through the proposed approach was revealed to be the highest for the microgrid scenario PV–WT–FC–battery converter (MG_3) followed by the PV–FC–battery converter (MG_4) microgrid scenario. The PV–DiG–battery converter (MG_6) scenario was adjudged to be the inferior of all possible microgrid scenarios.
- The results of the sensitivity analysis revealed the importance of the risk appetite of the expert in providing the evaluations. The ranking results were observed to be almost stable with respect to the criteria weights.
- The previous case studies solved using the proposed approach showed a strong interrelationship between the obtained ranking results and, hence, the validity of the obtained ranking results for the microgrid scenarios.

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Conflict of interest statement

The authors doesn't have association or financial involvement (i.e. consultancies/advisory board, stock ownerships/options, equity interest, patents received or pending, royalties/honorary) with any organization or commercial entity having a financial interest in or financial conflict with the subject matter or research presented in the manuscript.

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Pyrolytic conversion of agricultural residue using continuous auger reactor for resource recovery

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ABSTRACT

In this research work, agricultural residue was pyrolytically converted in a continuous semi pilot auger reactor. Studies have been carried out with variation in operating conditions such as temperature, and its effect on product yield and quality has been analyzed comprehensively. It was found that with increase in temperature from 400 to 500 ℃, the oil yield increased; however, reduced on further increasing the temperature. The char yield decreased from 50 to 20 wt% and gas yield increased with rising temperature. For cotton stalk pyrolysis, maximum biochar yield of 51% was obtained at 400 ℃, whereas maximum bio-oil yield of 46.5% was obtained at 500 ℃. Maximum gas yield of 55% was obtained with mustard husk feedstock at 700 ℃ temperature. Water content of the cotton stalk bio-oil (35%) was found to be lower than mustard husk bio-oil (79%). The water content in bio-oil was found to enhance with increase in temperature. GC-MS analysis confirmed that different chemical value compounds are present in the bio-oils obtained from both cotton stalk and mustard husk. In addition, the chars obtained had a calorific value of 24.15 MJ/kg for cotton stalk and 24.57 MJ/kg for mustard husk. At 500 °C, biochar showed good thermal stability in TGA analysis and major weight loss occurred in the temperature range of 500–600 ℃. It was also observed that biochar contains high amount of micronutrients and can be used for improving crop productivity by partially replacing synthetic fertilizers.

1. Introduction

With a phenomenal increase in the world population, it is expected that there will be a crunch in the fuel inventory by 2050 [1]. In addition, with the usage of fossil fuels and rapid industrialization, increased carbon emissions are leading to global warming across the globe causing catastrophic events. Therefore, to meet the energy demands and to reduce the environmental impact, renewable energy resources are being studied extensively which can potentially replace the fossil fuels. This led to enhanced interest in the utilization of biomass-based feedstocks which increased the share of bioenergy up to 13.5% in 2018 and ranked 4th among all the types of energy resources [2]. Biomass has shown a greater impact on controlling the atmospheric concentrations of greenhouse gases, leading to low carbon economy [3–7]. Countries around the globe are striving to achieve carbon-neutral environment as the carbon emissions from burning of fossil fuels have negative impact on the atmosphere [8]. Agro waste is the residue after harvesting of crops and includes stems, leaves, and stalks [9], that mainly consists of hemicellulose, cellulose, and lignin [10]. Agricultural residues has the potential to contribute significantly towards the production of renewable fuels using energy efficient conversion processes [11,12].

The leading producers of mustard are the Canada, Russia, China, and India, with a total annual production of 85 MT where ~14% of the world's total production comes from India in the year 2022 [13]. Cotton is produced in ~32 million hectares with an approximate yield of 786 kg/hectare worldwide having a production of 115 Million bales for the

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year 2022 as reported by the United States Department of Agriculture (USDA) [14].

Cotton stalk and mustard husk pyrolysis in different type of reactors is reported by many researchers. Al Afif et al. [15] studied the pyrolysis of cotton stalk biomass in a lab scale batch reactor by varying the temperature from 300 °C to 800 °C. Considerable biochar yield of 46.5% was obtained at 400 °C and oil yield up to 33% at 800 °C. Temperature was found to have a major influence on the process in terms of its mass and energy yield. Slow pyrolysis of cotton stalk by Chouhan et al. [16] obtained 17% bio-oil yield with 38% bio-char. The bio-oil was found to have a lower water content of 9.7% with a calorific value of 18.36 $MJkg^{-1}$. Ayse and Putun [17] also used a similar fixed tubular reactor to quickly pyrolyze cotton stalk and straw at 400–700 °C. They obtained highest oil yield of 39.51% at 550 °C with a sweeping gas flow of 200 cm^3min^{-1}. Pyrolysis of cotton stalk carried out by Yingquan et al. [18] in a fixed bed reactor reported an optimum temperature range between 550 °C and 750 °C with the charcoal produced having a higher calorific value of 28 $MJkg^{-1}$ and a larger surface area of > 200 $m^2.g^{-1}$ and the calorific value of the gas ranging between 8 and 9 MJm^{-3}. The bio-oil yields of 0.05 kg/kg of cotton stalk pyrolysis in a batch reactor was reported at 850 °C by Chen et al. [19]. Putun et al. [20] investigated the catalytic pyrolysis of cotton stalk in a Heinze-type reactor fixed bed to see the influence on liquid and solid products yields and composition. With a particle size range of $0.85 < D_p > 1.85$ mm, pyrolysis of cotton stalk at a final temperature of 550 °C produced an oil yield of 23.82%. The oil production attained a maximum of 24.77% in a sweep gas environment (100 cm^3/min of N_2 flow rate) of particle size and nitrogen flow rate. Chen et al. [21] have studied the changes in the CaO/biomass (Ca/B) mass ratios and pyrolysis temperatures in which they suggested that CaO might operate as a reactant, absorbent, and catalyst at Ca/B ratios of <0.2, > 0.2, and > 0.4, respectively. Maximum oil yield up to 50% were reported at 600 °C and in the presence of CaO. Fast pyrolysis of cotton stalk was reported by Zheng Ji-lu et al. [22] at 480–530 °C in a fluidized bed reactor where maximum bio-oil yields of ~55 wt% were obtained at 510 °C and it is claimed that the obtained bio-oil can be directly used as a fuel oil in a boiler. Similar studies of cotton stalk pyrolysis in a fluidized bed reactor were reported by Sui et al. [23] in the range of 400–600 °C with four condensers at different temperatures. The condenser with 0 °C collected almost 90% of tiny molecular compounds such as acetic acid, ketones, aldehydes, and water, whereas the 100 °C condenser collected organics with mid-boiling points (Phenols).

Since most of the studies reported are carried out in batch reactor, these results may not be useful for continuous operations and for process scale up. Studies with auger reactor were reported by Somsak et al. [24] for the pyrolysis of cassava rhizome that resulted in highest oil output of 50 wt%, and heating value of 28.5 $MJ.kg^{-1}$, were attained at 550 °C. Sand was used as the heat carrier during the pyrolysis process, and 2 kg. h^{-1} of feed was added throughout the process. The operating parameters used for these studies resulted in the bio-oil having a lower water content but a greater solid particle content. Barley straw and wood pellets pyrolyzed in a twin co-axial auger by Yang et al. [25] produced 28% char, 18% gas, and 54% oil. Both the reactor and the hot gases filter were progressively heated to 450 °C throughout the experimental campaign and maintained at that temperature for 30 min. Pyrolysis of hardwood, softwood, wheat straw, and wheat bran in a twin-auger by Henrich et al. [26] have shown that when compared to other feeds, soft and hard woods generated oil in higher proportions of 69.1 wt% and 66.5 wt%, respectively.

Although, majority of the research till date was reported using lab and batch scale reactors [27–29], in this study biomass pyrolysis was carried out extensively in a semi-continuous pilot scale auger reactor [30]. Two different biomass feeds obtained from discrete locations was studied at distinct temperatures and analyzed in terms of their product yield and composition. Change in composition of the oil with respect to temperature have been examined with focus of this research being the chemical value of oil rather than its fuel value. Characterization of bio-oil, the functional groups and other biochar properties was studied. These results help in evaluating the feasibility of the pilot scale demonstrations and addressing the issues pertaining to such large scale systems.

2. Experimental section

2.1. Materials and methods

Cotton stalk and mustard husk used in this study were obtained locally and converted into pellets. The average length and diameter of the pellet was ~4.6 ± 1 cm and ~0.6 ± 0.2 cm, respectively.

2.2. Experimental set-up

2.2.1. Auger reactor

The customized reactor has a processing capacity of 1–10 $kg.h^{-1}$ of biomass. It is fitted with three electrical heating zones that may be operated individually, enabling to adjust the reactor's internal temperature. Using a variable frequency drive, the screw rotation speed may be changed during operation from 5 rpm to 15 rpm, which maintains the feedstocks residence time inside the reactor. The reactor outlet is attached with two condensers in which the first condenser was maintained at 25 ± 5 °C with tap water circulation and the second condenser was maintained at 10 ± 5 °C with ice-cold water circulation.

2.2.2. Experimental procedure

Schematic diagram of the continuous flow auger reactor used in this study is shown in Fig. 1 which consisted of three heating zone, each having a 7.5 KW capacity. In the first series of trials, temperatures were increased by 100 °C steps between 400 °C and 700 °C in an oxygen-deficient environment. Tests were run for 90 min with a reactor screw speed of 5 rpm until no more substantial gas release would occur which is noticed with a gas flow meter attached to the reactor. Oil fractions were collected separately from the two condenser vessels (V_1 and V_2) that are analyzed for its composition and water content. The aqueous and oil phases of the liquid product were separated and weighed, whereas char was extracted from the collection chamber. The amounts of oil and char obtained was measured and the gas yields was calculated by difference.

2.3. Characterization techniques

Bio-oil fractions were analyzed using a Gas chromatograph Mass Spectrometry (GC-MS) analyzer (Shimadzu, Model: QP2020) to quantify their chemical contents. This was equipped with a column (Rxi-5 MS) having dimensions (30 m × 0.25 mm ID and 0.25 μm film thickness) and the method used for analysis was as follows: The GC column was maintained at an oven temperature of 50 °C and an injection temperature of 250 °C. Helium as a carrier gas was maintained at 1.18 mL/min with split ratio of 15. The column oven temperature was initially held at 50 °C for 2 min and then increased at a rate of 6 °C/min to 90 °C, followed by another 6 °C/min increase to 120 °C. The temperature was then increased at a rate of 8 °C/min to 250 °C and finally at a rate of 10 °C/min to 280 °C. The MS ion source temperature was set to 230 °C, while the interface temperature was maintained at 250 °C. Prior to the analysis, the oil samples were pre-processed in which 200 mg of pyrolysis oil was dissolved in 10 mL of solvent (acetone/hexane). Samples were diluted with solvent and dehydrated using 4 g of anhydrous sodium sulphate before being filtered through a 0.22 m syringe mesh filter [31]. The water content was determined using the Karl Fischer Titrator (1760 by ESICO).

Thermo Gravimetric Analysis (TGA) of feed and biochar was carried out through Shimadzu T6O with 20°C/min in nitrogen atmosphere. The carbonaceous residue was measured in accordance with ASTM D 524-Ramsbottom [32,33].

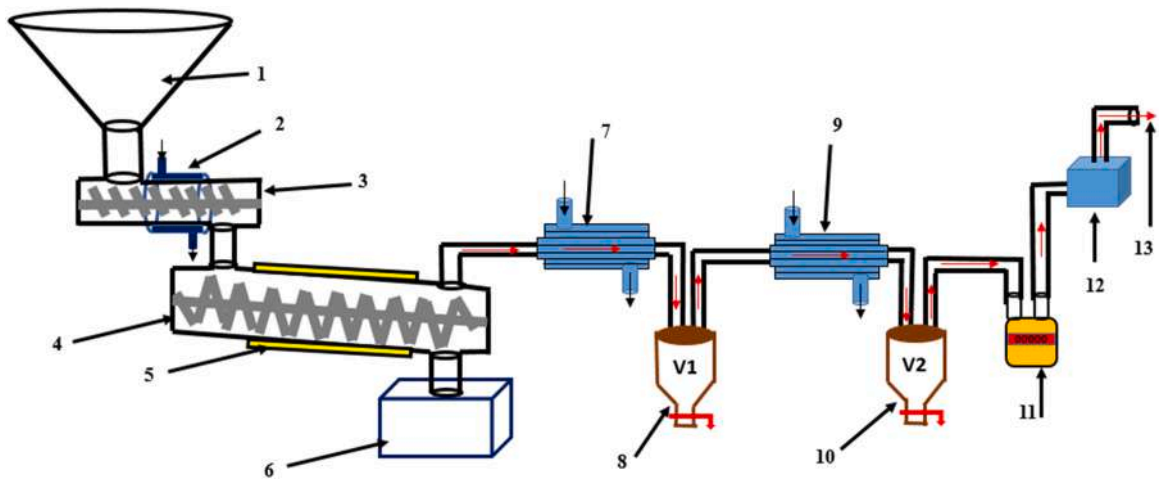

Fig. 1. Schematic of continuous auger pyrolysis reactor used in this study. 1. Hoper, 2. Cooling Jacket, 3. Feeder, 4. Reactor, 5. Heatingzone, 6. Char collector chamber 7. Condenser 1, 8. Oil collector vessel V1, 9.Condenser 2, 10. Oil collector vessel V2, 11. Gas flow meter, 12. Scrubber, 13.Vent gases.

The elemental analysis was performed using an LECO-Truspec CHNS analyzer. ASTM D7582 and ASTM D3176 standards were followed in determining the proximate and ultimate analysis. For in-depth analysis and characterization of the feed and product samples, a variety of instrumentation techniques are used such as scanning electron microscopy (SEM; JEOL make JSM-7610 F-Plus), and Fourier transform infrared spectroscopy (FTIR; Bruker alpha). FTIR analysis was done in transmittance mode to identify the functional groups in char and oil. SEM/EDX was carried out to determine the surface morphology of the char samples and to qualitatively determine the presence of different components in the char samples.

3. Results and discussion

3.1. Feed analysis

Ultimate and proximate properties of cotton stalk and mustard husk show that the cotton stalk having high ash content and low fixed carbon compared to mustard husk and with no changes in other properties.

Thermogravimetric analysis (TGA) is used to examine the thermal degradation behaviour of the feedstocks by varying the temperature from 400° to 700°C. Initial weight loss occurred up to 120 °C due to the removal of bound and unbound moisture present in the feed material as shown in Fig. 2 and around ~10% moisture removal was noticed for both the feedstocks. Decomposition of hemicellulose and cellulose starts at around 280 °C and 340 °C and within this temperature range, some extent of lignin also decomposes. With both the feeds, the residue obtained was similar having ~18% after 800 °C and the Differential thermogravimetric (DTG) curves for both the feeds also showed identical thermal decomposition ranging from 400° to 600°C.

Table 1
Proximate and ultimate analysis of biomass feed.

Parameters	Cotton stalk	Mustard husk
Loss on drying @ 110 °C (%)	4.50	6.40
Ash @ 800 °C (%)	4.73	3.68
Volatile Matter (%)	71.10	69.30
Fix Carbon (%)	19.67	20.62
Carbon (%)	44.94	44.47
Hydrogen (%)	7.32	6.03
Oxygen (%)	46.85	48.09
Nitrogen (%)	0.69	0.54
Sulphur (%)	0.20	0.87

3.2. Product yield distribution

The current study mainly focusses on the pyrolysis of cotton stalk and mustard husk biomass in an auger reactor. Biomass pyrolysis was carried out in the temperature range of 400 °C – 700 °C for both the feedstocks.

In case of cotton stalk, the oil yield was 34.5% at 400 °C which further increased up to 46.5% at 500 °C as shown in Fig. 3(a). With further increase in the temperature, no significant change in oil yield was obtained and thus, the optimum temperature was considered as 500 °C. Maximum char yield of 51.1% was obtained at 400 °C, which decreased with increase in temperature and lowest char yield of 17% was obtained at 700 °C. The gas yield gradually increased with increase in temperature and maximum gas yield of 51.7% was observed at 700 °C. This is due to the vapour phase thermal cracking of volatiles as well as the decomposition of char at higher temperatures. Similar observations of product trends were seen with the mustard husk where maximum oil yield of 46% was obtained at 500 °C as shown in Fig. 3(b). The optimum temperature was found to be similar to that of cotton stalk. Char yield was observed to be low as compared with cotton stalk. 47% char was observed at 400 °C and it decreased to 19.5% at 700 °C. The gas yields with mustard husk were found to be higher when compared with cotton stalk. No significant changes in the gas yield were observed at 400 °C and 500 °C, and it raised from 18% to 55% with increase in temperature from 500 °C to 700 °C.

The oil yields from different condenser fractions at different temperatures for both the feeds are shown in Fig. 4 It is evident from the figure that maximum oil was collected in V_1 condenser compared to V_2 condenser which is relatively operated even at lower temperature. Mainly because most of the volatiles were condensed with normal water at room condition and rest were condensed at lower temperature in condenser 2. For both the feeds, the yield trend recorded in both condensers revealed that oil yield rose with increasing temperature up to 500 °C, but then decreased in condenser V_1 above this temperature. While, with increasing temperature the oil fraction in the second condenser V_2 increased steadily with temperature up to 700 °C.

In Fig. 5, a comparative study of cotton stalk pyrolysis carried out in different reactors (fixed bed and fluidized bed) are summarized with respect to the obtained oil yields. In literature, no studies were found using continuous auger reactors for both cotton stalk and mustard husk. Most of the studies used lab scale fixed bed reactors, followed by few pilot scale operations with fluidized bed reactors. In a fixed bed reactor, cotton stalk was employed as granular powder with a particle size of < 1 mm, and a maximum oil yield of 50% was reported. However, a maximum oil yield from cotton stalk pyrolysis of 55% was produced in a fluidized bed reactor with 0.20 – 0.42 mm size of cotton stalk [34]. In

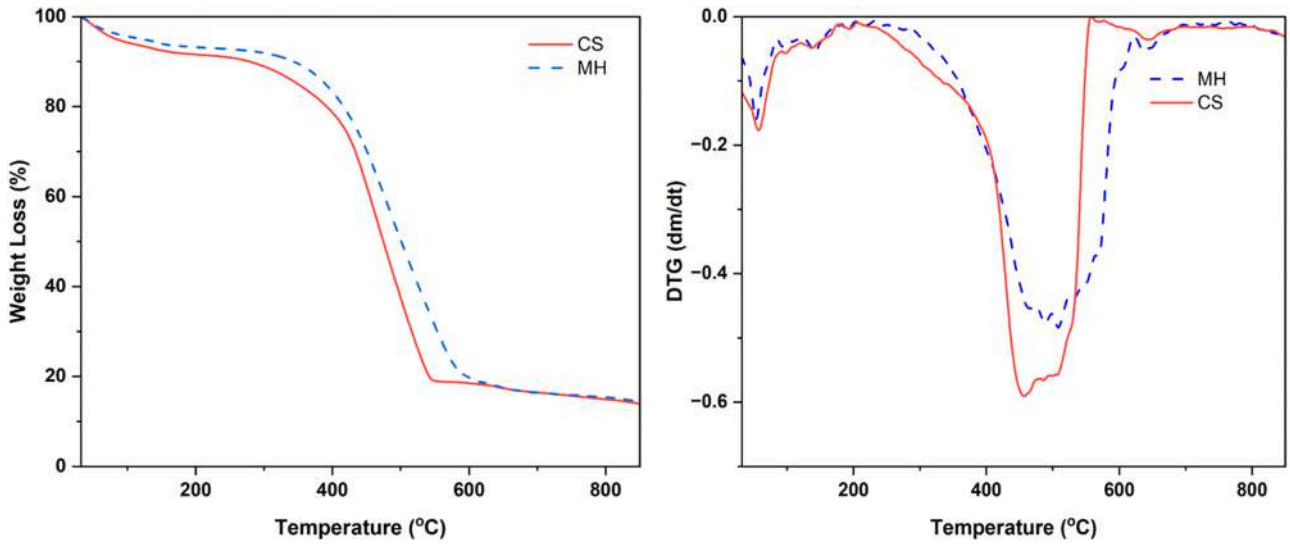

Fig. 2. (a) TGA and (b) DTG of Cotton stalk and Mustard husk feedstock.

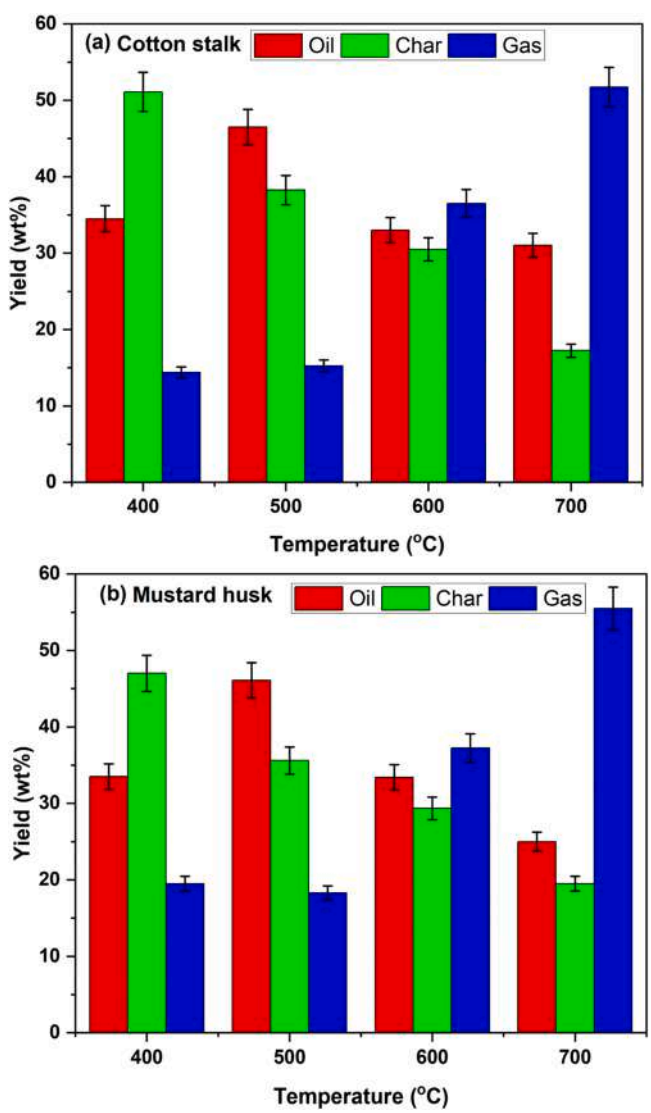

Fig. 3. Pyrolysis product yields of a) cotton stalk and b) mustard husk pyrolysis at different temperatures [Total feed input – ~3 kg; Screw rpm – 5].

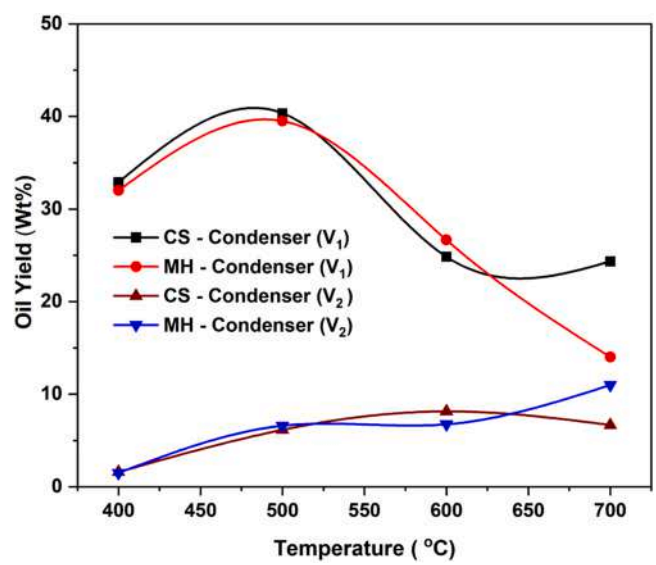

Fig. 4. Bio-oil yield distribution of cotton stalk and mustard husk at different temperatures obtained in different condenser fractions (V_1 & V_2).

the current study, the maximum bio-oil recovered, from the continuous auger reactor using the cotton stalk pellets with the size of 30 – 40 mm was ~ 46.5 wt%. In contrast to the studies mentioned above, where particles sizes of < 1 mm are used, in this study larger pellets were used with a size of > 30 mm, which favors secondary cracking reactions, a particle size of 2 mm is usually the upper limit because any further growth will accelerate the secondary pyrolysis reaction and lower the production of bio-oil.[35].

3.3. Oil analysis

The oil fractions obtained were analyzed using acetone (polar) and hexane (non-polar) for composition. As shown in Fig. 6, the chemical composition of the oil was classified into aliphatic, ketone, phenolic, nitrogenous, acid, alcohols, furan and others. It is evident from the figure that the composition of oils was relatively different with different solvents owing to its solubility. With acetone as a solvent, it was observed that oil produced from cotton stalk mainly consisted of high amounts of aliphatic such as 4,5-dihydro-2,4,4-trimethyl-, 3-

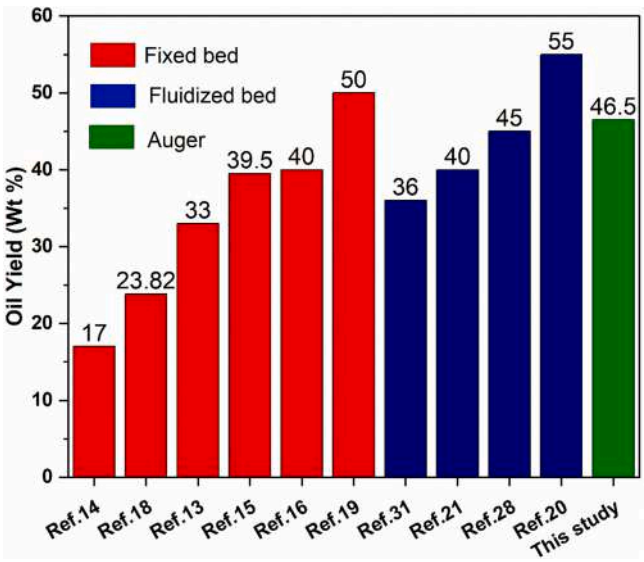

Fig. 5. Cotton stalk Pyrolysis oil yields comparison with literature.

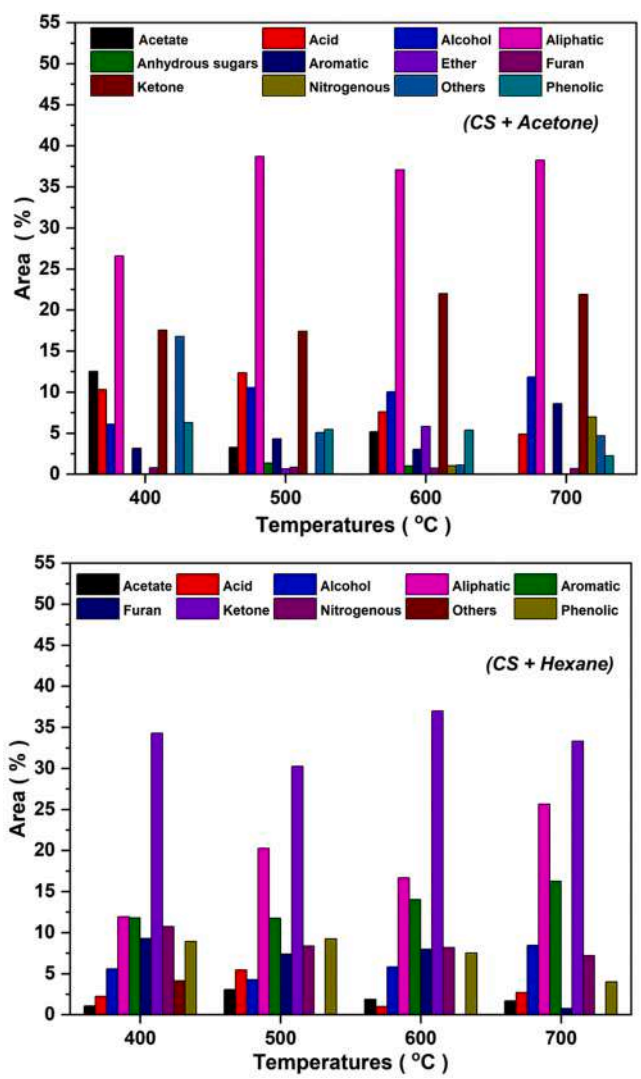

Fig. 6. Cotton stalk bio-oil composition analysis using polar (acetone) and non-polar (hexane) solvents.

Cyclopentene-1,2-diol, cis-, Hexadecane, and 1-Tetracosene. With increase in temperature from 400 °C to 500 °C, the amount of aliphatic increased from 26% to 39%. On further increasing the temperature, there was no significant change in the yield of aliphatics. Ketones were the second highest compounds present in the bio-oil and the amount of ketones were increased with increase in temperature. Ketones mainly contain 3-Penten-2-one, 4-methyl-, 1, 2-Cyclopentanedione, 3-methyl-, and Cyclohexanone, 4-acetyl- etc. Acetates were also present in good amount at 400 ºC, which decreased with increase in temperature. The amount of phenolic compounds remained constant for the entire temperature range. Alcohols were gradually increased with temperature from 400 °C to 700 ºC. Higher amount of acids were present at 500 °C, which reduced with further increase in temperature.

Hexane as a solvent mainly dissolved the non-polar compounds present in the oil. Higher amount of ketones were present, followed by the aliphatics and acids, in the bio-oil as shown in Fig. 5. In case of hexane, it contained Cyclopentane, 1-acetyl-1,2-epoxy-, 2-Hexanone, 3,4-dimethyl-, entanal, 2,2-dimethyl-, Bicyclo[3.1.1, heptan-2-one. 3, 4-Dihydroxy-5-methyl-dihydrofuran-2-one, 2-Cycopenten-1-one, Cyclopentane, 1-acetyl-1, 2-epoxy-, 1, 2- Cyclopentanedione, 3-methyl. Aromatic compounds were found to be increased with increase in temperature when compared, the CS bio-oil had high amounts of aromatic compounds (e.g., Toluene, 2 H-Imidazole, 2,2,4,5-tetramethyl-, Pyrazine, 2,6-dimethyl-, Styrene, Ethylbenzene, Benzene, 1,2,4-trimethyl-, Oxazole). Most of the nitrogenous compound and furan present in the bio-oil were dissolved in Hexane solvent. These compounds typically consisted of Pyridine, 2-methyl-, N, N-Dimethylacetamide. alpha.-Methyl-.alpha.-propylsuccinimide, Pyrazine, methyl-) and (2-Furanmethanol, tetrahydro-, 2-Furanone, 2, 5-dihydro-3, 5-dimethyl. Other than these compounds, acetates, acids and alcohols were also present in the CS bio-oil.

Acetone extracted bio-oil obtained from mustard husk showed high amounts of aliphatics (~47%) with increase in temperature. The aliphatics content reduced while the ketone content increased at higher pyrolysis operating temperatures. As shown in Fig. 7, mustard husk bio-oil had a good amount of anhydrous sugars which were almost absent in the oil produced from cotton stalk. Bio-oil contained a good amount of alcohols and phenolic compounds. Bio-oil obtained at high temperature had large amounts of mixed and unidentified compounds which may possibly be due to the interaction of different compounds. Major compounds identified in the bio-oil were Propanoic acid, 1-methylethyl ester, 1-Tridecene, Hexadecane, D-Allose, 1-Nonadecene, 1-Pentadecene, 1,2-Cyclopentanedione, 3-methyl-, 2-Furanmethanol, Oxazole, 4,5-dihydro-2,4,4-trimethyl.

Hexane extraction of bio-oil mainly consisted of ketones that was present in higher amount (40%) at 500 °C. The yield of aromatic compounds which includes Toluene, Phenol, p-Xylene were increased with temperature. In case of mustard husk, aliphatics content increased with temperature with maximum yields achieved at 600 °C as shown in Fig. 7. At lower temperatures, the yields of acidic components was found to be maximum which decreased significantly with increase in temperature. Overall, aliphatic, ketone, phenolic and acid compounds were present large amounts in the bio-oil for both cotton stalk and mustard husk. The trend of graphs for acetone and hexane were almost similar. With both extraction solvents (hexane and acetone), the aliphatic and ketones were majorly extracted followed by phenolic compounds. Majority of the hydrophenolics, carbohydrates, and sugars in their aqueous states came from lignocellulosic biomass. Furan is produced because of the hemicellulose and phenolic bonds that were cleaved during the breakdown of the β-O-4 link in the lignin [36].

Fourier Transform Infrared Spectroscopy (FTIR) analysis of bio-oil at different temperatures ranging from 400 °C to 700 °C was done to identify accompanying functional groups in the products. Spectral output for pyrolysis oil was shown in Fig. 8. The large absorbance peak of O–H stretching vibration of 3305 cm^{-1} confirms the alcohol and phenol groups in the pyrolysis liquid. The H_2O release can also be the

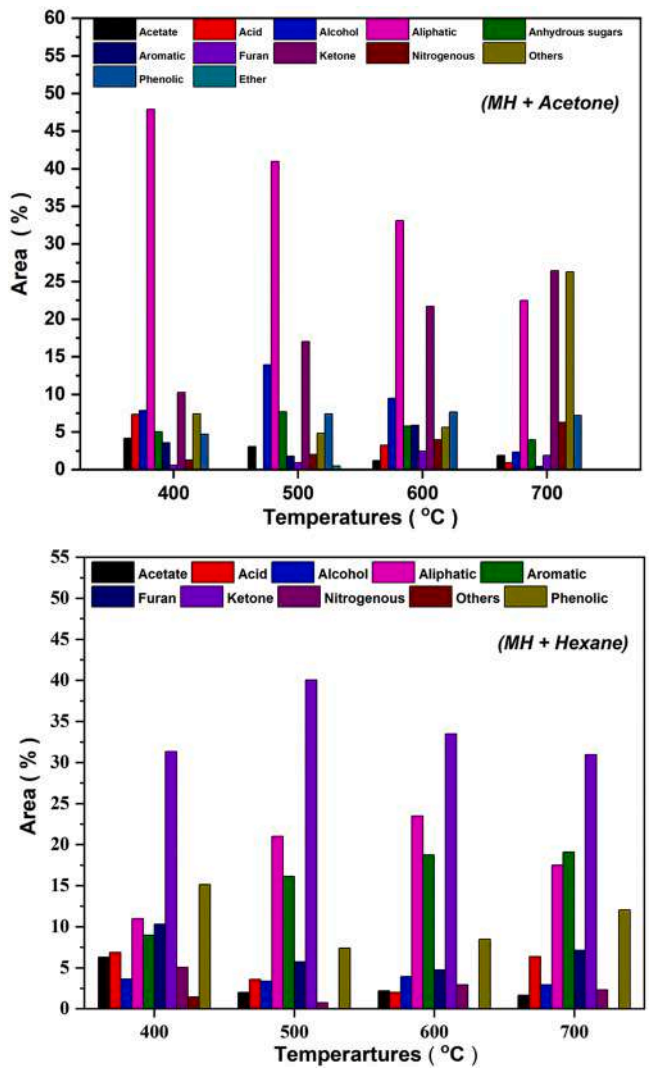

Fig. 7. Mustard husk bio-oil composition analysis using polar (acetone) and non-polar (hexane) solvents.

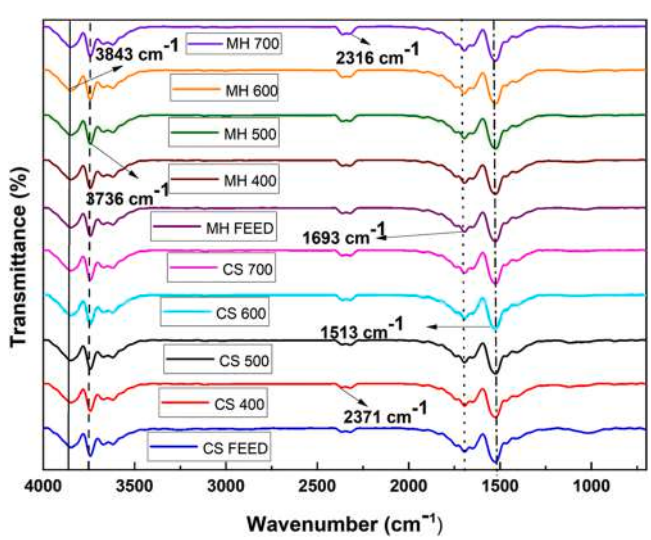

Fig. 8. FTIR spectra of bio-oil fractions at different conditions.

reason for it. The presence of ketones and aldehydes is connoted by the presence of C═O absorbance peak at 1645 cm^{-1}. The medium narrow absorbance peak of C–C bond vibration of 1449 cm^{-1}, indicates the methyl group [37]. Alcohols, carboxylic acids, ethers, and esters were represented by the potential absorbance peak of C–O bond of wave number 1112–1374 cm^{-1}.

The amount of water present in the bio-oil obtained from both feedstocks at various temperatures is shown in Fig. 9. Cotton stalk bio-oil was found to have a lower water content than mustard husk bio-oil. Cotton stalk oil was found to have a minimum water content of 35 wt % of water and a maximum of 72 wt%, whereas mustard husks had a minimum of 79% and a maximum of 90%. These findings demonstrated that oil's water content increased when temperature was raised which may be attributed to the possible dehydration reactions that are favoured at 500 °C. In this work, cotton stalk oil was found to be superior compared to mustard husk oil.

The obtained oil samples from different feeds were also analysed in terms of the carbon residue and it was found that the carbon residue dropped from 26 wt% to 12 wt% with increase in temperature from 400 °C to 600 °C for the oils obtained from CS and MH. Based on these results, reforming these oils could result in the formation of coke, leading to a potential loss of up to 12 wt% of carbon in the form of coke. Low temperature oils tend to have a more coking tendency compared to high temperature oils.(Table 1).

3.4. Char analysis

The operating conditions of the reactor was found to be crucial for the creation of organic biochar in this experimental work, having its effects apparent not only in biochar yield but also in terms of its physicochemical properties, as indicated in Table 2. When cotton stalk and mustard husk were heated to temperatures between 400 °C and 700 °C, the total organic carbon (TOC) content in the biochar increased from 56.80 wt% to 63.10 wt% and 61.10–64.10 wt%, respectively, while the total hydrogen and nitrogen content decreased in both the biochar. Imam et al. [38] also provided a description of a comparable investigation. According to the scientists, deprivation of hydrogen occurs as a result of the cleaving of biochar's weaker structural connections, which results in a carbon-rich substance. According to the current research, the highest carbon content was 64.10 wt% for mustard husk and 63.10 wt% for cotton stalk. This enhanced carbon to a nitrogen ratio (C/N) of around 37.88 and 47.46 in biochar produced from cotton stalk and

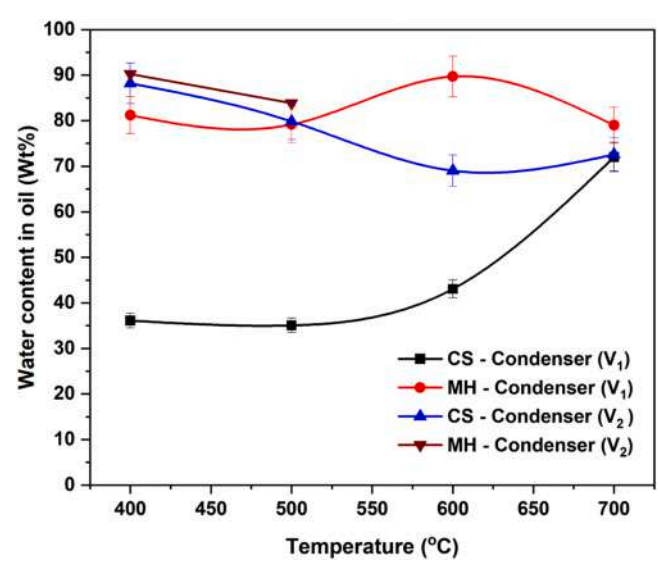

Fig. 9. Bio-oil water content of cotton stalk and mustard husk obtained from different condensers (V_1 and V_2).

Table 2
Proximate and ultimate analysis of biochar at different temperatures.

Parameters	Cotton stalk				Mustard husk			
	400 °C	500 °C	600 °C	700 °C	400 °C	500 °C	600 °C	700 °C
Loss on drying @ 110 °C (%)	5.89	5.30	6.62	6.67	5.42	6.12	5.69	7.59
Volatile Matter (%)	40.21	38.62	28.01	36.64	43.08	59.74	42.63	43.37
Fix Carbon (%)	30.48	36.85	25.6	35.31	25.68	15.47	13.92	19.67
Ash @ 800 °C (%)	23.42	19.23	39.77	21.38	25.82	18.67	37.76	29.37
Carbon (%)	56.80	63.10	62.30	61.60	61.10	61.80	64.10	62.60
Hydrogen (%)	3.18	2.07	1.48	1.02	3.03	2.65	1.17	0.87
Nitrogen (%)	1.86	1.80	1.74	1.63	1.72	1.49	1.45	1.32
Sulphur (%)	0.36	0.38	0.40	0.23	0.58	0.29	0.38	0.24
Oxygen (%)	37.8	32.65	34.08	35.52	33.57	33.77	32.9	34.97
H/C	0.06	0.03	0.02	0.02	0.05	0.04	0.02	0.01
O/C	0.67	0.52	0.55	0.58	0.55	0.55	0.51	0.56
C/N	30.55	35.15	35.86	37.88	35.5	41.56	44.32	47.46
(N + O)/C	0.70	0.55	0.58	0.60	0.58	0.57	0.54	0.58
Calorific Value (MJ/kg)	21.84	24.12	24.15	23.85	26.64	23.01	24.57	23.54
pH	8.74	8.61	8.03	7.99	8.21	8.5	8.44	8.11

mustard husk, respectively. In both situations, the amount of volatile substances dropped as the temperature rose and the amount of fixed carbon increased.

Since plants immediately absorb inorganic nitrogen via their root systems, nitrogen (N) is one of the most important nutrients to impact plant development and productivity [39,40]. Total nitrogen content is influenced by pyrolysis temperature; for both feeds, it first increases at low temperatures and further reduces at higher temperatures. The biochar's strength is influenced by the feedstock biomass utilised and the manufacturing circumstances. In this investigation, we found that cotton stalk and mustard husk biochar both contained 1.86 wt% and 1.72 wt% nitrogen, respectively.

Furthermore, Spokas' research [41] on the stability of biochar in soil revealed that a lower oxygen-to-carbon (O/C) ratio produced biochar that was more stable. The study concluded that biochar would probably have a half-life of less than 100 years when the oxygen-to-carbon molar ratio (O/C) is larger than 0.6. If it falls between 0.2 and 0.6, the half-life will be between 100 and 1000 years. The half-life is larger than 1000 years if the oxygen to carbon molar ratio is less than 0.2. The oxygen-to-carbon ratio in the present experimental investigation was 0.67 for cotton stalk and 0.56 for mustard husk; as a result, the biochar that was formed is expected to be more stable in the soil with a half-life of between 100 and 1000 years[41]. Biochar formed at 400 °C just for cotton stalks has an O/C ratio of 0.67, indicating a half-life of less than 100 years. Similar to this, the H/C ratio is a reliable predictor of the carbon structure and soil stability of biochar. The degree of aromatization in the biochar generated is indicated by the lowest hydrogen-to-carbon molar ratio (H/C), which was found in biochar made from cotton stalk and mustard husk to be 0.02 and 0.01. At least 70% of the organic carbon in biochar is anticipated to persist in soil for at least 100 years with 95% confidence when the H/C molar ratio is less than or equal to 0.4[42]. In this investigation, it was discovered that the biochar generated used less or the same amounts of H/C and O/C molar ratios as biochar produced in a batch-type reactor utilising a variety of agricultural wastes, animal dung, grasses, and wood [43–45]. The hydrogen and oxygen concentration of char decreases as the temperature rises. H/C ratio drops from 0.06 at 400 °C to 0.02 at 700 °C for cotton stalk and from 0.05 at 400 °C to 0.01 at 700 °C for mustard husk, showing an increase in the aromaticity and carbon-rich nature of char. Also, the drop in the ((O+N)/C) ratio, also known as the polarity index, suggests a decrease in the surface polar functional groups of biochar produced from cotton stalk at elevated pyrolysis temperatures [46]. Both cotton stalk and mustard husk exhibited high calorific values of up to 24.15 MJ kg^{-1} and 24.57 MJ kg^{-1} at varying temperatures of operation. All pH values of biochar examined in this work were in the alkaline range and were not substantially affected by an increase in temperature.

In Fig. 10, the surface morphology of char samples made from agricultural residues that were examined using a scanning electron microscope (SEM) at various temperatures is demonstrated. It was observed that the char surface contains high amount of pores which can reduce soil bulk density and can increase its porosity, and thus enhances

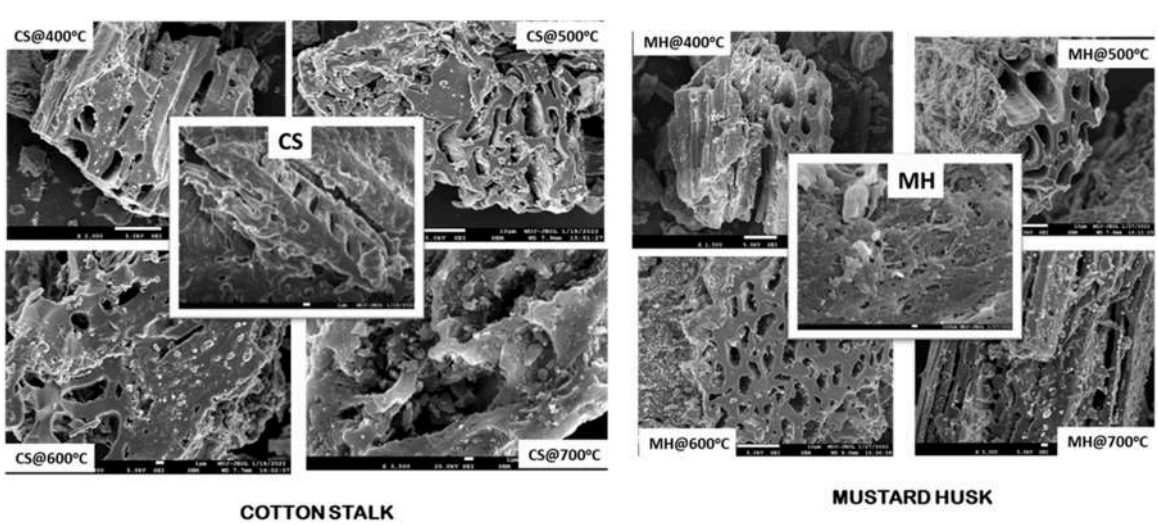

Fig. 10. FESEM analysis of cotton stalk and mustard husk biochar.

Table 3
Elemental analysis of biochar at different temperatures.

Elements	Cotton stalk (wt%)					Mustard husk (wt%)				
	Feed	400 °C	500 °C	600 °C	700 °C	Feed	400 °C	500 °C	600 °C	700 °C
C	48.7	55	70.9	74.8	75.2	36.4	55.8	78.6	81.4	80.3
O	40.4	26.6	13.3	16.3	16.4	55.7	18.6	10	13.3	10.2
Mg	0.6	0.8	1	0.9	1	1.1	1.3	0.5	0.8	0.5
Si	1.5	1	0.5	0.9	0.3	0.2	0.7	0.4	0.5	0.4
P	0.7	0.7	0.9	0.4	0.5	0.3	0.7	0.8	0.6	0.6
S	1.2	0.7	0.9	0.7	0.5	1.2	1.3	1.1	0.3	1.2
K	4.2	0.8	5.3	4.4	5	2.3	9.6	6	2.5	4.0
Ca	2.7	14.4	7.2	1.7	1.1	2.9	11.9	2	0.6	2.4

the soil properties for harvesting. It also increases the water retention capacity. The pyrolysis reaction conditions, and the composition of biomass influences the surface morphology and the quality of the biochar. Biochar showed different pore sizes which were mainly in the size range of 0.5–5 μm.

Energy Dispersive X-Ray analysis showed that carbon content of the biochar produced from cotton stalk and mustard husk increased with increase in temperature as shown in Table 3. High carbon content in the biochar at higher temperature was mainly due to the fixed carbon present in the feed materials. Biochar contains good amount of micronutrients which includes P, K, Mg, Ca and S. Mustard husk contains high amount of potassium (K) compared with cotton stalk. Elemental oxygen decreased from 26.6 wt% to 13.3 wt% for cotton stalk and 18.6–10 wt %. for mustard husk. Overall, with increases in temperature, the carbon density increased in the biochar. The oxygenated compounds were decomposed at higher temperature.

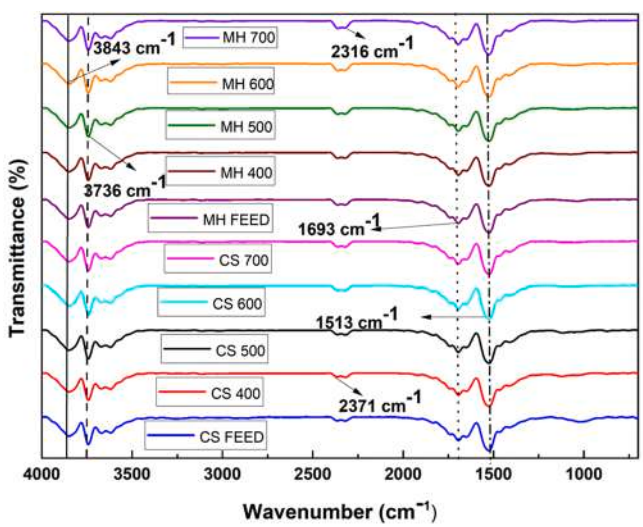

Fig. 11. FTIR spectra of biochar at different conditions.> .

Functional groups in the char was analysed using Fourier Transform Infrared Spectroscopy (FTIR) at various temperatures ranging from 400 °C to 700 °C. Fig. 11 display the spectral result for the char produced during pyrolysis. Presence of aromatic C–H group was observed at 2371 $cm^{-1}$and 2316 $cm^{-1}$and it confirms the occurrence of N–H functional group [47]. The peak at 1693 cm^{-1} represents the stretching of carbonyl bonds (C═O) of the carboxylic groups or conjugated ketone. Corresponding weak R-OH band was also found in the band 3900–3700 cm^{-1} representing a monomeric alcohol, phenol and carboxylic groups.

3.4.1. *Thermal decomposition behaviour*

Thermal stability of biochar samples obtained at different conditions was analysed through TGA studies as shown in Fig. 12 where it can be observed that with increasing pyrolysis conditions the moisture content of the char from cotton stalk increased from 5% to 10%. No significant weight loss (< 5%) with respect to moisture content in the mustard husk was noticed with increasing pyrolysis temperature. It is noteworthy that the biochar of mustard husk obtained at lower pyrolysis temperatures decomposed rapidly at 500 °C while mustard husk biochar obtained at 600 °C and 700 °C were relatively stable enough and degraded very slowly. Similar behaviour of biochar decomposition was noticed with cotton stalk derived biochar. The final residues or mineral matter of different biochar derived from cotton stalk and mustard husk at different

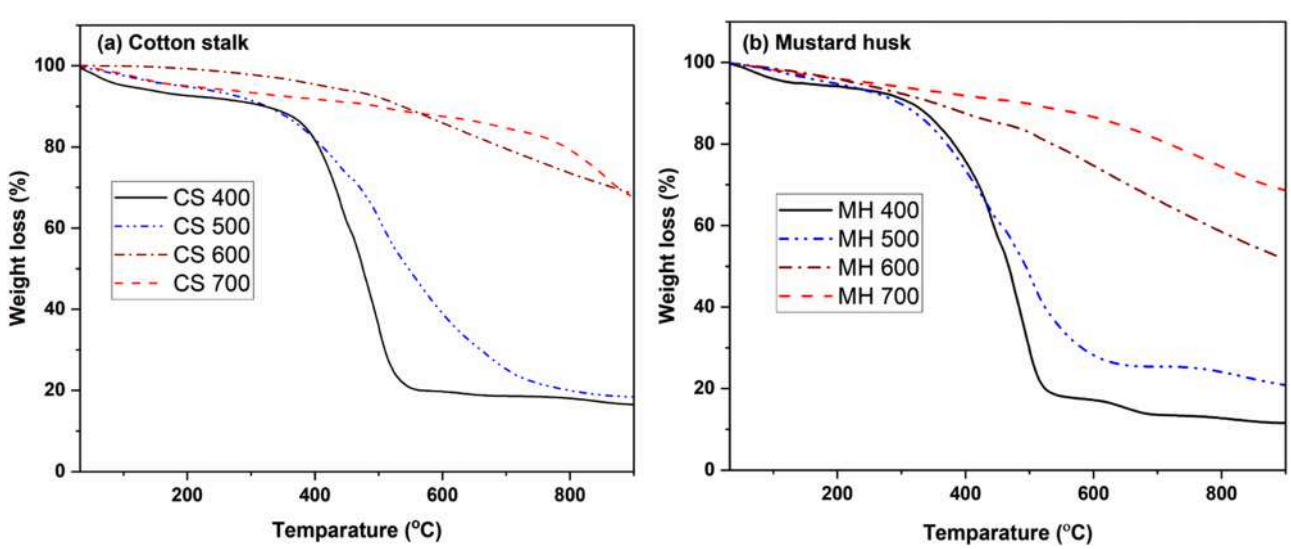

Fig. 12. Thermal decomposition behaviour of the obtained biochar (a) Cotton stalk and (b) Mustard husk at different conditions.

conditions is in the range 10–25%.

4. Conclusions

In this study, continuous slow pyrolysis of cotton stalk and mustard husk in auger reactor at different temperatures ranging from 400° to 700°C is reported. Results showed that with increase in temperature, the oil yield increased up to 500 °C and reduced beyond this temperature. The char yield decreased, and gas yield increased with increasing temperature. The product yield with mustard husk is quite similar to that of cotton stalk feed. However, the water content in cotton stalk bio-oil was found to be lower than mustard husk bio-oil, and the water content was found to be increasing with temperature. Oil analysis indicated presence of aliphatic, ketonic, phenolic and acidic compounds in bio-oils obtained from both the feedstock. Additionally, the chars obtained have high calorific and nutrient value, and can be used for various agricultural and non-agricultural applications. The results of these studies are highly promising and will lay the foundation for process scale up and product upgradation using such agricultural residue material.

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CRediT authorship contribution statement

Sivasankar Kakku: Conceptualization, Investigation, Methodology, Validation, Writing – original draft. **Sowkhya Naidu**: Investigation, Methodology, Validation, Writing – review & editing. **Mukesh Bhatt**: Investigation, Methodology, Writing – review & editing. **Anand G. Chakinala**: Validation, Supervision, Writing – review & editing. **Jyeshtharaj Joshi**: Writing – review & editing. **Shina Gautam**: Writing – review & editing. **Kaustubha Mohanty**: Writing – review & editing. **Gaurav Kataria**: Writing – review & editing. **Abhishek Sharma**: Conceptualization, Validation, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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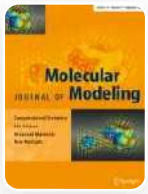

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Abstract

Context

In this work, the corrosion inhibitive effect of acetoxime derivative of zinc chloride, ($ZnCl_2.2HON{=}C(CH_3)_2$) (ZA), was investigated on mild steel in epoxy/polyamide coating. ZA was used to modify diglycidyl ether of bisphenol A (DGEBA) to yield novel anticorrosive coating (epoxy-ZA) with excellent barrier characteristic. The dispersal of ZA may lead to the formation of Zn–O–C and O–Zn–O linkages in the polymer framework which act as inorganic fillers producing a dense structure of hybrid coating. In electrochemical findings, electrochemical impedance spectroscopy (EIS) and Tafel polarization (TP) indicate higher protection efficiency for epoxy-ZA coatings (99.99 and

99.93 % for EIS and TP, respectively) as compared to others. Using surface analysis and electrochemical data, it was concluded that an inhibition synergy was developed when ZA was taken instead of acetoxime or zinc chloride (ZC) alone in the coating formulation.

Methods

Fourier transform infrared (FT-IR) was used to investigate epoxy interaction with zinc compounds and scanning electron microscopy (SEM) was used to investigate morphology of the samples. To reinforce the experimental results, reactivity of crosslinked epoxy and epoxy-ZA coatings with metallic surface was also explored using density functional theory (DFT) with basis set B3LYP/6-311G(d,p) and molecular dynamics (MD) methods by using Forcite module. Modification of epoxy with ZA enhances its interaction with steel surface in dry as well as in wet conditions as indicated by the adhesion energy calculated by MD simulations.

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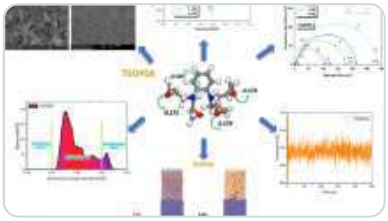

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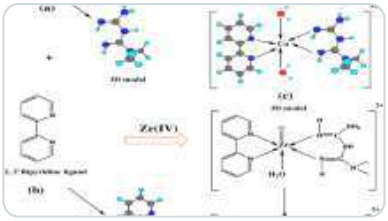

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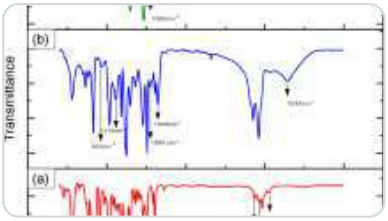

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Data availability

The authors confirm that the data supporting the findings of this study are available within the article (and/or) its supplementary materials.

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Ishita Chopra: rough draft of computational work was done by her.

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Ethics declarations

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The authors declare no competing interests.

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Climate trends and maize production nexus in Mississippi: empirical evidence from ARDL modelling

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Climate change poses a significant threat to agriculture. However, climatic trends and their impact on Mississippi (MS) maize (*Zea mays* L.) are unknown. The objectives were to: (i) analyze trends in climatic variables (1970 to 2020) using Mann–Kendall and Sen slope method, (ii) quantify the impact of climate change on maize yield in short and long run using the auto-regressive distributive lag (ARDL) model, and (iii) categorize the critical months for maize-climate link using Pearson's correlation matrix. The climatic variables considered were maximum temperature (Tmax), minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), relative humidity (RH), and carbon emissions (CO_2). The pre-analysis, post-analysis, and model robustness statistical tests were verified, and all conditions were met. A significant upward trend in Tmax (0.13 °C/decade), Tmin (0.27 °C/decade), and CO_2 (5.1 units/decade), and a downward trend in DTR (−0.15 °C/decade) were noted. The PT and RH insignificantly increased by 4.32 mm and 0.11% per decade, respectively. The ARDL model explained 76.6% of the total variations in maize yield. Notably, the maize yield had a negative correlation with Tmax for June, and July, with PT in August, and with DTR for June, July, and August, whereas a positive correlation was noted with Tmin in June, July, and August. Overall, a unit change in Tmax reduced the maize yield by 7.39% and 26.33%, and a unit change in PT reduced it by 0.65% and 2.69% in the short and long run, respectively. However, a unit change in Tmin, and CO_2 emissions increased maize yield by 20.68% and 0.63% in the long run with no short run effect. Overall, it is imperative to reassess the agronomic management strategies, developing and testing cultivars adaptable to the revealed climatic trend, with ability to withstand severe weather conditions in ensuring sustainable maize production.

Maize is the most important cereal, known as the "queen of cereals[1]." The United States (US) is the leading producer, followed by China, Brazil, and Argentina[2]. The US contributes 32% to global production, and 60% of total production is exported[2]. Within the US, Mississippi (MS) is the state that contributes 748.3 million USD annually to national maize revenue[3]. Mississippi has 0.64 million acres under maize cultivation[4]. Mississippi has eight of the total twelve soil types, 60% of cropland is irrigated (by center pivot and furrow), and maize is grown on raised beds[5,6]. Mississippi has registered its maize yield progressing at a faster annual growth rate than the US for the past two decades[7]. As a result, MS actual maize yield surpassed the US in 2000; the current yields for MS and the US are 12.51 and 11.87 Mg ha^{-1}, respectively[4]. Over the past half-century, MS has experienced a rapid increase (173%) in the harvested acres for maize compared to the US average (47%)[4]. More intriguingly, MS maize still has a considerable yield gap of 2 to 5.6 Mg ha^{-1}, or 14 to 31%, at the state level when compared to the highest achievable yield under best management practices[7]. Closing these yield gaps is critical for economic benefits, reducing food prices, and consequently improving food security[8]. Strategies to close existing yield gaps via research necessitate a broader understanding of the causal factors and their extent on variations in crop yield[9].

The factors that govern crop production and its variability include genetics, environment, and management such as soil properties, and agronomic management for instance fertilization, irrigation, tillage, planting dates,

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row-to-row width, planting population, planting time, depth, etc.,[10,11]. However, amongst all, the climate is noted to be the major uncontrollable contributor affecting crop production, with the proven potential to explain up to or even greater than 60% of the global crop yield variations[12]. Numerous studies on wheat (*Triticum aestivum* L.)[13–16], maize[17–19] and rice (*Oryza sativa* L.)[20,21] has demonstrated a consensus on crop-climate link in cereals. Based on region-specific studies, the crop-climate association was found to be strong, ranging 22–60%, 40–71.3%, and 67–92% in wheat, maize, and rice, respectively. The same has been confirmed by global studies for other crops as well[22–25]. Specifically, in maize, Rizzo et al.[26] attempted to separate climate, management, and genetic factors and deduced that climate change (48%) explained most of the yield variation, followed by management (39%), and genetics (13%). Given the alarming rate of future climate warming, almost 1.5 °C upsurge, precipitation (PT) irregularities (24–40%) combined with increased carbon emissions, the coefficient of yield dependability on climate is expected to rise further by 47% in 2050[27].

Climatic trends induce biotic and abiotic stresses in plants by controlling microclimates around them, and influence evapotranspiration, gas exchange, resource use efficiency, plant-microbe relations, phenological processes, crop performance, and finally yield[28]. The severity of crop-climate links is determined by the magnitude and trend of change of climatic variables, which vary by region, and such estimates for MS are lacking[29]. Mississippi is in a climatically vulnerable southeastern region of the US, and has a significant agroeconomic impact[30,31]. Also, Mississippi agriculture relies on reduced capital investments and infrastructural inputs, removing several choices for combating climate-related negative consequences[32,33]. Even so, only a few climate-crop studies were conducted so far for MS[34–37], and even fewer on maize[21,38,39]. Therefore, the current study is aimed at calculating (i) the trend in climatic variables, namely, daily maximum temperature (Tmax), daily minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), carbon emissions (CO_2), and relative humidity (RH) in MS during 1970–2020, and (ii) impact of change in these variables on MS maize yield. The novelty of this study lies in investigating climatic variables other than just temperatures and PT, monthly investigations of trends in climatic variables, pinpointing crucial months impacting maize and employing econometric method for the first time to explore crop-climate link in MS.

Methodology

A detailed step-by-step outline of the various methodologies used to accomplish the study's objectives is displayed in Fig. 1. The sections below provide a detailed discussion on the various methodology components, including data, study model specifications, and the estimation procedures involved.

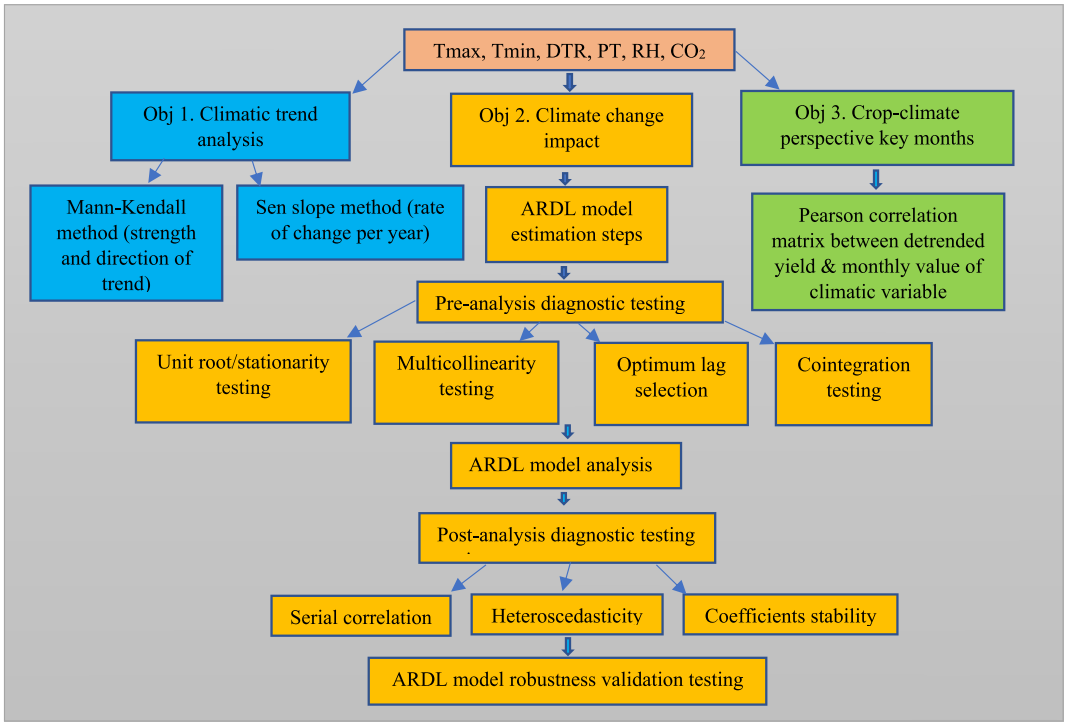

Figure 1. A step-by-step flowchart outlining the detailed methodology for the three different objectives. The first objective—estimating the trend for each of the six climatic variables—maximum temperature (Tmax), minimum temperature (Tmin), diurnal range (DTR), precipitation (PT), relative humidity (RH), and carbon dioxide emissions (CO_2)—is shown in blue boxes on the left, the second objective—quantifying the overall impact of climatic variables on maize yield—are shown in yellow boxes in the middle, and the third objective workflow—identifying the key months for crop-climate linkage—are shown in green boxes on the right.

Data

The present study utilized the past 50 years of time-series dataset for MS (Fig. 2), from 1970 to 2020 similarly to previous studies[12,40–42].

As per World Meteorological Organization guidelines, 30 years (at minimum) dataset is recommended for climatic trend computations[43]. The response variable was maize yield, and the explanatory variables were Tmax, Tmin, DTR, PT, RH and CO_2 (Fig. 1). Harvested area (HA) was included as an input control variable as suggested by Jan et al.[44]. Moreover, following Chandio et al.[40], the Tmax, Tmin, DTR, and RH were averaged, and PT was totaled to maize growing season (MGS) for analyzing the impact of growing season anomalies. Also, the monthly averaged data of each variable was utilized to compute the month-wise climatic impact on maize. The MGS (March-September) was taken as per the USDA harvesting and planting dates handbook. The data on CO_2 was available on a yearly average basis. The data were gathered from the USDA-NASS repository (https://www.nass.usda.gov/) for yield, National Oceanic and Atmospheric Administration (NOAA) database (https://www.noaa.gov/) for Tmax, Tmin, DTR, and PT, PRISM database (https://prism.oregonstate.edu/comparisons/) for RH, and US energy information administration (https://www.eia.gov/environment/emissions/state/) for CO_2. There is a vast literature authenticating the use of time series data and the aforesaid data sources for crop-climate estimations[45–48].

Econometric model specification

The two-dimensional effects of climate change on crops include a short-term effect that is directly impacting the yield in the current and subsequent (residual effect) years[49,50]. This immediate effect accumulates to build the foundation for permanent effects, referred to as long-term effects, that ultimately influence the soil-forming processes, soil properties, microbial buildups in the soil, and nutrient-use abilities[51–53]. Therefore, the study evaluated both the short and long-term relationships between the variables using the widely used auto-regressive distributive lag (ARDL) bound-testing method[44,54–58]. The ARDL model is preferred over other statistical methods because it can efficiently run the analysis for both short-term and long-term relationships simultaneously at ceteris paribus keeping all other variables unchanged[55]. Moreover, the ARDL model accounts for previous year inputs/factors influencing the current year yield, by incorporating the "lag length" component in its functionality[59]. These factors could be residual effects of previous year fertilization especially if a granular form is applied, late season excessive rainfall, or maybe rollover effects of previous crop rotation[60,61]. By regressing the lag values of the regressors against the regressand, the lag length feature statistically advises the ARDL model on how far back in time it needs to go to capture the residual effect[62,63]. The ARDL model works well regardless of the integration level of the time series data *i.e.,* level (I = 0), at first difference (I = 1), or combination of I (0), and I (1)[56]. The ARDL approach is robust against endogeneity issues, which arises when the dependent variable tends to correlate with the error term in the regression model[64], reducing residual correlation, and small sample sizes[54]. The ARDL has an intrinsic feature of error correction model (ECM) that estimates the pace (% per year) with which the short-term effects transfer cumulatively to form permanent basis for the long-term effects[54]. The following linear equation was used to evaluate short-term and long-term association of mentioned variables:

$$Y = f(Tmax, Tmin, DTR, Prec, RH, CO_2, HA) \tag{1}$$

The natural log form variables are suggested for time series data to smoothen multicollinearity and instability issues if any[56].

$$\begin{aligned} lnY_t = &\beta_0 + \beta_1 \ln(Tmax)_t + \beta_2 \ln(Tmin)_t + \beta_3 \ln(DTR)_t + \beta_4 \ln(PT)_t \\ &+ \beta_5 \ln(RH)_t + \beta_6 \ln(CO_2)_t + \beta_7 \ln(HA)_t + \varepsilon_t \end{aligned} \tag{2}$$

Figure 2. The study area (Mississippi state) highlighted on the USA map.

where, Y_t is maize yield (Mg ha^{-1}) in year ***t***. Tmax, Tmin, and DTR are in (°C), PT in (mm), RH in (%), CO_2 in metric ton, HA is maize harvested in hectares, β_0 is intercept, and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ are coefficients of slopes in the function, and ε_t is error term in time *t*.

Auto-regressive distributive lag (ARDL) bound test approach

The ARDL model equation adopted in similar previous studies[44,55,57], is used here as follow:

$$\begin{aligned}\Delta lnY_{it} =& \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta \ln(Y)_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta ln(Tmax)_{t-i} \\ &+ \sum_{i=1}^{n} \alpha_3 \Delta ln(Tmin)_{t-i} + \sum_{i=1}^{n} \alpha_4 \Delta ln(DTR)_{t-i} + \sum_{i=1}^{n} \alpha_5 \Delta ln(PT)_{t-i} \\ &+ \sum_{i=1}^{n} \alpha_6 \Delta \ln(CO_2)_{t-i} + \sum_{i=1}^{n} \alpha_7 \Delta ln(RH)_{t-i} + \sum_{i=1}^{n} \alpha_8 \Delta ln(HA)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_1 \Delta ln(Y)_{t-i} + \sum_{i=1}^{n} \gamma_2 \Delta \ln(Tmax)_{t-i} + \sum_{i=1}^{n} \gamma_3 \Delta ln(Tmin)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_4 \Delta ln(DTR)_{t-i} + \sum_{i=1}^{n} \gamma_5 \Delta ln(PT)_{t-i} + \sum_{i=1}^{n} \delta_6 \Delta ln(CO_2)_{t-i} \\ &+ \sum_{i=1}^{n} \gamma_7 \Delta ln(RH)_{t-i} + \sum_{i=1}^{n} \gamma_8 \Delta \ln(HA)_{t-i} + \emptyset(ECT)_{t-i} + \varepsilon_t\end{aligned} \tag{3}$$

where *Y* is maize yield, *t* is the time in year, *i* is the lag order with n is the highest lag value, α_0 is the intercept, Δ denotes the first differencing, ε_t is the error term, α_1 to α_8 represents coefficients of long term cointegration for different variables, γ_1 to γ_8 are short term coefficients for different variables, ECT is the error correction term and $\varnothing$ is its coefficient which determines the pace (% per year) by which short term climatic impacts cumulatively transfer to form basis for permanent long term effects.

The first differencing, as suggested in previous studies[23,65], was applied as a technique to detrend the maize yield to account for the other yield impacting unobserved factors such as advancement in agricultural technology, progression of the adjustments in growers according to the management recommendations, and the infrastructural developments. The data on aforesaid factors was not available. Detrending is widely used in literature to exclude (minimize) the impact of such unobserved variables and to capture the sole impact of climate variables on crop yields[23,65].

Climatic trend analysis

The Mann-Kendall test[66,67] and Sen slope method[68] were employed to time series (1970–2020) data for all study variables to establish the trend on both monthly and growing seasonal timescale (Mar-Sep). Both these non-parametric tests are recommended by the World Meteorological Organization for climatic trend estimation[69]. The Kendall tau computes the direction and strength of the trend where positive sign of the coefficient indicates increasing (upward), negative sign signifies decreasing (downward) trend, and the magnitude of 0–0.25 (weak), 0.26–0.50 (fair), 0.51–0.75 (moderate), and values above 0.76 (strong) signifies the strength of the trend[70–72]. However, the Sen slope coefficient indicates the rate of change per year. For more detailed understanding on methodology of both these tests, readers are suggested to read Gocic and Trajkovic[73] or Gujree et al.[74] procedures.

Estimation procedures

Unit tests

Units root problem arise when the mean, variances, and co-variances are time dependent or non-constant during the study timeframe[75]. Usually, unit root problems (non-stationarity) exist with time series data, if it exists, can cause spurious regression[76]. When a single coefficient fails to accurately reflect the true relationship between the study variables, false regression occurs, and the conclusions drawn may be untrue[76]. Hence, the Augmented Dickey-Fuller (ADF)[77] and the Phillips–Perron tests (PP)[78] unit root tests were performed. The results revealed that all the variables were stationary at level or first differencing, fulfilling the assumption of ARDL bound testing model (Table 1A).

Multicollinearity testing

Analyses involving multiple variables may be susceptible to multicollinearity due to the propensity of variables to become correlated with one another[79]. To avoid overfitting in a regression model caused by multicollinearity, either the variables exhibiting it should be eliminated, or it needs to be verified that the data is free of multicollinearity, using tests such as the variance inflation factor (VIF) test and tolerance test[80]. The present study performed both these tests and found that the VIF value (3.45) and tolerance value (0.30) were within the permissible limits (Table 1B); VIF < 10 and tolerance value (TOV) > 0.1[42,79,80], confirmed that multicollinearity was not an issue with the dataset (Table 1B).

Variables	ADF		PP		
	Level	First difference	Level	First difference	
(A) Unit root test results following Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests of variables including maximum temperature (Tmax), minimum temperature (Tmin), carbon dioxide emission (CO_2), harvested area (HA), precipitation (PT), and maize grain yield (Y)					
Tmax	−6.276***		−10.036***		
Tmin	−6.340***		−10.580***		
CO_2	−2.256	−8.400***	−2.264	−8.357***	
HA	−3.237	−8.323***	−3.170	−10.284***	
PT	−6.317***		−6.287***		
Y	−7.058***		−7.054***		
Variable	**Variance inflation factor (VIF)**	**Tolerance value (TOV)**			
(B) Multicollinearity test results based on variance inflation factor (VIF) and tolerance value (TOV) tests of variables including maximum temperature (Tmax), minimum temperature (Tmin), carbon dioxide emission (CO_2), harvested area (HA), and precipitation (PT)					
Tmax	4.512	0.221			
Tmin	4.126	0.242			
CO_2	3.207	0.312			
PT	2.475	0.404			
HA	2.937	0.340			
Mean value	3.451	0.304			
Lag	**SMLR**	**FPE**	**AIC**	**SIC**	**HQ**
(C) Model's lag selection criterion using sequential modified statistics test (SMLR), final prediction error (FPE) test, Akaike information criterion (AIC) method, Schwarz information criterion (SIC) method, and Hannan-Quinn information criterion (HQ) method					
0	NA	8.36e-13	−10.783	−10.544	−10.693
1	177.455	4.28e-14	−13.768	−12.099*	−13.142*
2	37.853	7.06e-14	−13.350	−10.249	−12.188
3	26.476*	3.42e-14*	−14.295*	−9.7631	−12.597
4	67.775	7.43e-14	−13.990	−8.0276	−11.756
Test Statistic	**Value**	**Significance (%)**	**Level I (0)**	**First difference I (1)**	
(D) The ARDL bounds cointegration test results					
F-statistic	7.228	10	2.08	3	
		5	2.39	3.38	
		1	3.06	4.15	

Table 1. Pre-analysis diagnostic testing. "***"shows the significance level at 1%. *Indicates lag order selected by the criterion, SMLR: sequential modified likelihood ratio test statistic, FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion, and each test at 5% level of significance.

Optimum lag selection

The ARDL model can determine the number of prior years to include in the model for regressing the explanatory variables (including their lag values) against the regressand (current year yield) by using the optimal lag number, to incorporate the previous years' residual effects on current year maize yield[55]. The study used statistical tests such as Sequential modified likelihood ratio (SMLR) test, final prediction error (FPE) test, Akaike information criterion (AIC) method, Schwarz information criterion (SIC) method, and Hannan-Quinn information criterion (HQ) method, as guided by Agbenyo et al.[57], and Warsame et al.[55], to select optimum lag length for the model.

The appropriate lag length for the ARDL model was determined to be three (Table 1C), based on the minimum value generated by majority of the tests (SMLR, FPE, and AIC) utilized. The lag length of three signifies that the previous three years data needs to be considered to regress against the regressand for capturing residual effects.

Cointegration testing

The Wald F-test was used for the null and alternative hypotheses testing after running a regression to check for the existence of cointegration between regressors and regressand[44]. The two types of threshold values were produced, the upper bound threshold values were termed I (1), and the lower bound threshold values were termed I (0). The null hypothesis is accepted if the Wald F-statistics value is less than the lower bound (at I = 0) threshold value, indicating no relationship present between the regressand and regressors[41]. However, the null hypothesis is rejected if the Wald F-statistics value is higher than the upper bound (at I = 1) threshold value, indicating the presence of a relationship between the regressand and regressors[41]. The Wald F-test value (Table 1D) was estimated as 7.228, which, at the 1% significance level, was higher than the upper critical limit (4.15). The absence

of cointegration was thus ruled out as the null hypothesis, and the presence of cointegration was determined at a 1% level of significance.

Post analysis diagnostic tests, and sensitivity/robustness check of ARDL model

After the ARDL model estimation, the study performed Breusch-Godfrey LM test (for serial correlation check), Breusch–Pagan–Godfrey test (for heteroscedasticity check), and cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals tests (for stability check of the model coefficients), as suggested by the previous studies[58].

The results confirmed that the functional model was free from serial correlation and heteroskedasticity (mis-specifications) issues (Table 2A). The CUSUM and CUSUMSQ test graphs found that the parameter plot lines were consistent, stable, and stayed within critical bounds at the 5% level of significance (Figs. 3 and 4). Hence, confirming the accuracy and stability of short and long run model coefficients that affected the MS maize yield from 1970 to 2020. The CUSUM test can identify systematic, whereas the CUSUMSQ test identifies rapid and drastic variations from the constancy of the model coefficients[81].

After confirming the ARDL model's goodness of fit and predictive effectiveness by running post-analysis diagnostic tests, the sensitivity analysis was carried out using the fully modified ordinary least square (FMOLS) model to examine the robustness of the ARDL model functionality in long run. The FMOLS model showed that Tmax and PT had a negative impact on maize yield while Tmin and CO_2 had a positive impact (Table 2B). These results are consistent with the long-run coefficients of the ARDL model, further validating the robustness of the model recommendations.

Test	Statistics	Probability		
(A) Diagnostic test results following Breusch–Pagan–Godfrey test, Breusch-Godfrey LM test, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) of recursive residuals tests, for the error terms of the regression equation obtained based on the ARDL model output				
BPG test for Heteroskedasticity	0.532	0.919		
BG LM test for Serial Correlation	0.841	0.443		
CUSUM	Stable	Figure 3		
CUSUM Squares	Stable	Figure 4		
Variable	**Coefficient**	**Std. error**	**t-Statistic**	**Prob**
(B) Results of fully modified ordinary least square (FMOLS) model for confirming the robustness and validation of the study model				
Tmax	−14.133	4.073	−3.469***	0.001
Tmin	7.735	2.524	3.064***	0.004
CO_2	1.374	0.574	2.396**	0.021
HA	0.252	0.115	2.180**	0.035
PT	−1.253	0.438	−2.858***	0.007
C	26.614	10.959	2.429**	0.019
R-square	0.828			
Adjusted R-square	0.808			

Table 2. Post analysis diagnostic testing. Tmax represents maximum temperature, Tmin: minimum temperature, CO_2: carbon emissions, HA: harvested acres for maize, and PT: precipitation.

Figure 3. Cumulative sum (CUSUM) plot of recursive residuals of ARDL model with 95% confidence interval around the null.

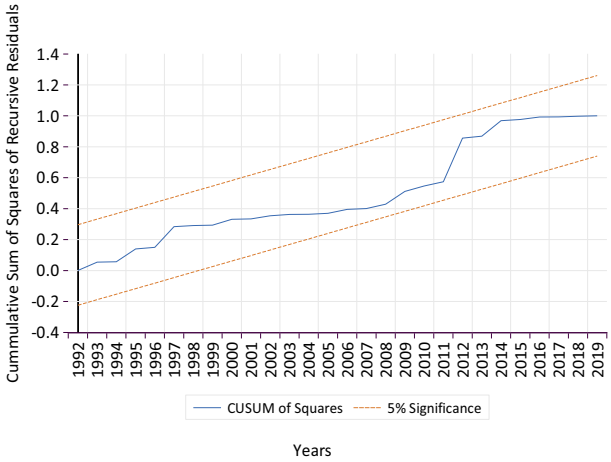

Figure 4. Cumulative sum (CUSUM) of squares Plot for recursive residuals of ARDL model with 95% confidence interval around the null.

Pearson's coefficient of correlation matrix

Pearson's coefficient of correlation between detrended (first differenced) yield and monthly averaged value of each climatic variable, as suggested by Eck et al.[82], was calculated. Based on the strength of correlation, the months that had the greatest impact on maize yield were pinpointed.

Results and discussions

The final regression fit equation used by the ARDL was a reduced model, which excluded DTR and RH since they were found to be non-significant and reducing the overall predictive efficiency of the model. Hence, the pre and post diagnostic tests (Tables 1, 2)—all of which were based on the ARDL model's assumptions—were only carried out for the variables that were part of the ARDL model. However, all variables were included for climatic trend analysis, and for calculating the Pearson's correlation between detrended (first differenced) yield and monthly averaged values of climatic variables (Tables 3 and 4B).

Climatic trend analysis

Tmax increased by 0.13 °C per decade in MGS, while Tmin increased by 0.27 °C per decade, which is 107.67% faster than Tmax (Table 3). Other studies have found similar unsymmetric Tmin-Tmax warming rates[83–86].

	Tmax		Tmin		DTR		PT		RH		CO_2	
Series\test	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope	Kendall tau	Sen slope
March	0.139	0.032	0.146	0.030	0.012	0.001	−0.095	−0.193	0.047	0.021	–	–
April	0.014	0.003	0.101	0.015	−0.078	−0.008	0.090	0.194	0.157	0.060	–	–
May	0.103	0.012	0.178	0.022	−0.092	−0.009	−0.087	−0.183	0.003	0.000	–	–
June	0.051*	0.007*	0.373***	0.035***	−0.261**	−0.028**	0.095	0.163	0.125	0.036	–	–
July	−0.006	−0.001	0.262**	0.024**	−0.401***	−0.031***	0.119	0.147	0.068	0.022	–	–
August	0.066*	0.009*	0.299**	0.027**	−0.201*	−0.019*	0.158	0.269	−0.009	−0.004	–	–
September	0.143	0.021	0.183	0.027	0.006	0.001	−0.063	−0.112	−0.110	−0.060	–	–
MGS	0.176*	0.013*	0.422***	0.027***	−0.252**	−0.015**	0.057	0.432	0.027	0.011	0.669***	0.514***
Mean	28.56 °C		16.02 °C		12.54 °C		48.49 mm		66.73%		53.58 million metric tons (Mmt)	

Table 3. The summarized results of the Mann–Kendall test and the Sen slope method for trend estimation of variables including maximum temperature (Tmax), minimum temperature (Tmin), diurnal temperature range (DTR), precipitation (PT), relative humidity (RH), and carbon dioxide emission (CO_2) in Mississippi from 1970 to 2020. Kendall tau negative (−) value signifies downward (decreasing) trend, and positive (+) value indicates upward (increasing) trend with its value ranging between -1 and 1, and its absolute value signifies the strength of the trend. As the absolute value of Kendall tau approach 1, the strength of the trend becomes strong. The Sen slope value represents the rate of change (of variable) per year. Kendall tau is a pure number (unitless) as it is a correlation coefficient and Sen slope units are °C/year (for Tmax, Tmin, and DTR), mm/year (for PT), percentage/year (for RH), and Mmt/year (for CO_2). The negative (−) value of Sen slope means the rate of decrease per year while the positive (+) value represents the rate of increase per year. Significance: "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$.

Variable	Coefficient	Std. Error	t-Statistic	Prob	
(A) Calculated ARDL model estimates for short and long run effects of Tmax, Tmin, CO_2, HA, and PT on maize yield (dependent variable)					
ARDL model long run effects					
Tmax	−26.330	9.169	−2.872***	0.008	
Tmin	20.684	6.731	3.073***	0.005	
CO_2	0.629	0.976	0.644**	0.032	
HA	0.155	0.154	1.007	0.323	
PT	−2.696	0.983	−2.742**	0.011	
ARDL model short run effects					
Tmax	−7.392	2.074	−3.563***	0.001	
Tmin	2.361	1.340	1.760	0.091	
CO_2	−0.061	0.623	-0.098	0.922	
HA	0.018	0.093	0.198	0.844	
PT	−0.645	0.249	−2.587**	0.016	
C	44.329	25.660	1.728**	0.096	
ECM	−0.302	0.038	−7.892***	0.000	
R square	0.834				
Adjusted R square	0.766				
	Climatic variables				
Growing season months	**Tmax**	**Tmin**	**DTR**	**PT**	**RH**
(B) Pearson's correlation matrix between the first differenced (detrended) yield and climatic variables (Tmax, Tmin, DTR, PT, RH) based on each month of MGS					
March	0.248	0.228	0.013	−0.251	0.103
April	0.062	0.129	−0.107	0.024	0.248
May	0.173	0.240	−0.123	−0.143	−0.024
June	−0.001**	0.485***	−0.420**	0.267	0.226
July	−0.159***	0.314*	−0.472***	0.132	0.190
August	−0.000	0.354**	−0.319*	−0.323*	0.022
September	0.213	0.231	−0.019	−0.098	−0.126

Table 4. Impact of climate change on maize yield. "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$. Tmax represents maximum temperature, Tmin: minimum temperature, DTR: diurnal temperature range, CO_2: carbon emissions, HA: harvested acres for maize, PT: precipitation, and ECM: error correction model. Significance codes: "*" $p < 0.05$, "**" $p < 0.01$, and "***" $p < 0.001$.

There was an upward trend for Tmax for MGS, specifically for June and August, but it was weak, as magnitude of correlation strength was less than 0.25 (Fig. 5A; Table 3). July was the only month that experienced a Tmax decreasing trend (Fig. 5A), yet non-significant (Table 3).

In contrast, MGS shows an upward trend for Tmin, increasing by 0.27 °C per decade in the last five decades (Fig. 5B; Table 3). Tmin warming rates ranged between 0.24 and 0.35 °C per decade in June, July, and August of MGS (Table 3). June, Tmin had the greatest rise, adding 0.35 °C per decade to global warming (Table 3). The equivalent rising trends were seen by Eck et al.[82] and Sharma et al.[87] in MGSs in the southeastern part of the US.

In recent years, the DTR (Tmax-Tmin) has been recognized as another climatic variable that is essential for diagnosis, particularly under rising unsymmetrical warming scenarios[88,89]. There was a downward trend for DTR in June, July, and MGS, and a weak trend for August (Fig. 5C). In MGS, the DTR decreased by 0.15 °C per decade, but in June, July, and August, it decreased by 0.19–0.31 °C per decade (Table 3). These rates are comparable with the computations of Sun et al.[90] for the other maize-growing regions.

Precipitation and RH, neither for MGS nor for any other month were found to indicate a significant trend line (Figs. 5D, 6A), although numerically, a negative trend was noted in March, May, and September for PT and August and September for RH (Table 3).

A moderately strong and significant upward trend and an annual increase rate of 0.51 units was noted for CO_2 (Fig. 6B; Table 3). The same is corroborated by Rahman[91] and Wu et al.[92] previously in the context of direction and strength, and by Ainsworth et al.[93] in the context of rate of increase.

The climatic impact on maize

The Tmax was found to have a significant negative effect on maize yield in both the short and long run (Table 4A). More specifically, every 1 °C rise in Tmax reduced the maize yield by 7.39% and 26.33% in the short and long run, respectively (Table 4A).

On further downscaling the analysis to monthly basis to capture the effect of within season variability, it was noted that the monthly averaged Tmax of June and July had a significantly negative correlation with maize yield (Table 4B). This indicates that Tmax in June and July (reproductive-early grain filling stages) contributed the

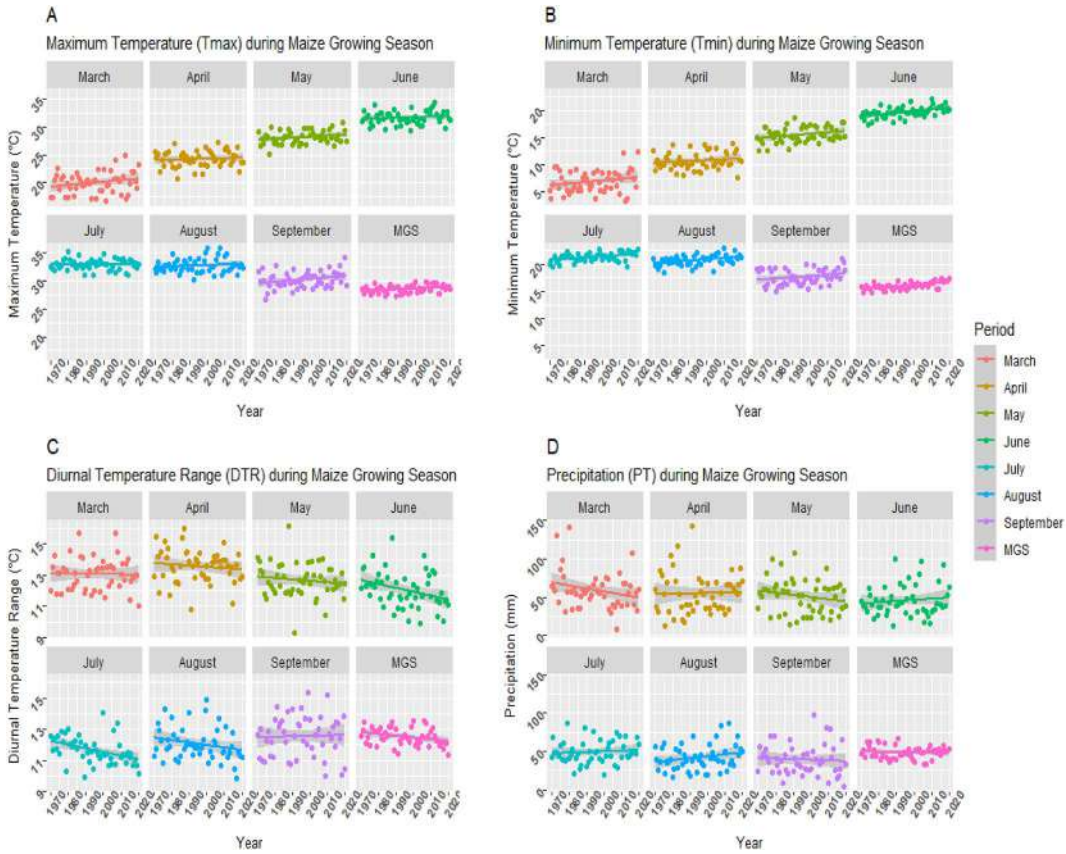

Figure 5. Trend lines for Tmax (**A**), Tmin (**B**), DTR (**C**), and precipitation (**D**) for maize growing season (MGS) and its individual months from 1970 to 2020 in Mississippi. Each figure is faceted by months from March to September and average of all months all together in MGS.

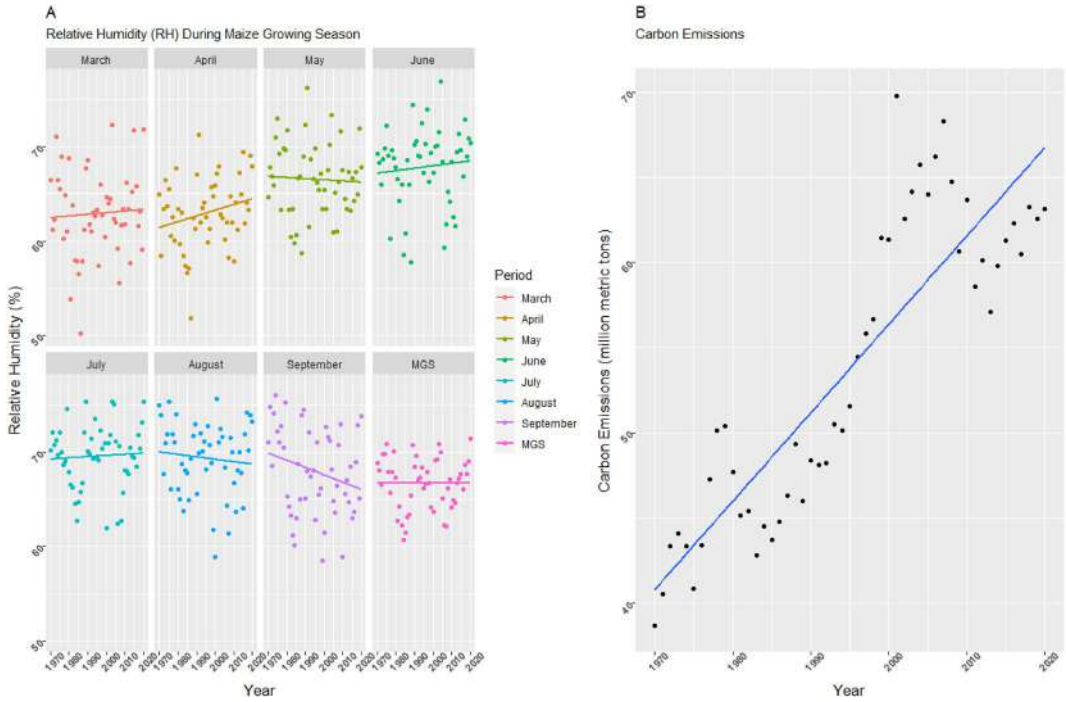

Figure 6. (**A**) Trend lines for relative humidity for maize growing season (MGS) and its individual months from 1970 to 2020 in Mississippi. (**B**)Trend line for CO_2 emissions for years from 1970 to 2020 in Mississippi. Figure A is faceted by months from March to September and average of all months all together in MGS.

most to yield loss in MS. This is because in reproductive stage, stress-induced plant dysfunction has irreparable harm on kernel development and yield which is not the case with the vegetative phase[94,95]. These findings are consistent with those of Kucharik and Serbin[17] in the context of highly correlated months with respect to maize growing season and to those of Lobell and Field[23], and Wu et al.[92] in the context of Tmax's adverse effects. Hu and Buyanovsky[96] reported that maize needs both a warming trend with temperatures higher than average in April and May to provide better conditions for germination and emergence and a cooling trend with temperatures lower than average in June-August to promote reproductive success and, consequently, yield. This statement is largely agreed with by Lobell and Asner[97] as well. However, MS had not seen any significant warming trend in April and May; instead, it showed an unfavorable significant warming trend in June and August (Table 3). Contrary to favorable conditions, MS was observed to have temperatures that were below average (28.56 °C) in April (24.24 °C) and May (28.13 °C) and above average in June (31.66 °C) and August (32.78 °C) (Table 3). The Mid-MGS (*i.e.*, the beginning reproductive stage) coincides with June and July (hotter climate), which affects tasseling and grain filling, thereby yield, and is sensitive to additional warming[98,99]. Furthermore, the average Tmax (28.56 °C) noted in MS for MGS (Table 3) has already surpassed the optimal temperature (26.40 °C) for maize[100], and is rapidly approaching 29 °C, which is damaging to maize[101]. The main reason is that after surpassing 29 °C[101,102] or 30 °C[103], processes such as anthesis-silking, assimilates production, translocation of resources during reproductive and grain filling are hampered. Temperature beyond this range has been linked to impaired pollen structure, decreased sugar (energy) levels upon anthesis, and retarded pollen shedding, all of which negatively affect pollen germination ability and fertilization[104]. More recent studies found that short duration of Tmax episodes during anthesis can cause significant reduction in pollen germination (30%), kernel number (72%), kernel weight (10%), and stomatal conductivity (52%) in maize[105,106]. Further at the biochemical level, the activity of the enzymes involved in converting atmospheric CO_2 to glucose or other key photosynthesis-related molecules were found to be disrupted by elevated temperatures[107]. In worst case scenario at higher temperatures, a yield loss could reach 34–80%[87,108].

A 1°C rise in Tmin increased maize productivity by 20.68% over the long run, indicating a significant and positive effect on maize yield in MS (Table 4A). Several other maize-growing regions have shown that yields respond to Tmin[87,109–111]. Tmin warming was also shown to be advantageous to maize yield in the short run, while the impact was not significant (Table 4A). Although there has not yet been an agreement regarding the physiological effects of Tmin on plants as there is an inclination of the crop-climate research towards the Tmax or Tavg and overlooking the Tmin[112,113]. The current study's findings on the positive association of Tmin and maize yield were supported by evidence from the literature, which included studies using statistical modeling[87,114–121] as well as simulation-based studies[122,123]. This is attributable to the fact that the increased Tmin speeds up night-time respiration, resulting in carbohydrates losses[124]. However, this carbon starvation enhances the following day photosynthetic rate to more than make up for the losses brought on by the accelerated night-time respiration, increasing overall plant productivity[125,126]. Consequently, the amassed dry matter from various plant tissues starts remobilizing toward grain, increasing maize kernel weight, and hence, the yield[127]. Also, the increased Tmin is believed to impart conducive conditions for germination, emergence, seedling growth, grain filling (during night-time), and milk-maturity stage in maize[110]. More importantly, according to Badu-Apraku et al.[127], Cairns et al.[128], and Sanchez et al.[100], all the beneficial mechanisms of Tmin mentioned above only prevail when the Tavg is below 25 °C or 26.40 °C. The Tavg for the current study was found to be 22.29 °C (Table 3). Furthermore, a similar case of Tavg of less than 25 °C was observed in all studies that supported the current findings, specifically at 21.2 °C and 24.4 °C in Liu et al.[116] and Shammi and Meng[36]. Contrarily, the studies that found negative effects of Tmin on maize yield were all found to have been carried out at Tavg of more than 25 °C[129]. For example, Wang et al.[130] tested at Tavg (27-31 °C), Liu et al.[131] tested at Tavg (25–35 °C), Suwa et al.[132] at Tavg (31 °C), and Wilhelm et al.[133] at 29.5 °C and observed negative Tmin-yield impact in maize. Furthermore, it was noted that June, July, and August demonstrated a significant and positive correlation between Tmin and detrended yield (Table 4B). This suggests that warmer nights in June, July, and August are beneficial for maize yields in MS, but there is no evidence that this beneficial effect offsets the detrimental effect of Tmax during the same months. Chen et al.[110] also noted 1 °C Tmin warming during May/September improved maize yield by 303/284 kg ha^{-1}. Reilly[134], Izaurralde et al.[135], and Reilly et al.[136] also realized the positive effects of warming on maize yield. Also, according to Schlenker and Roberts[137], Lobell et al.[138], and Lobell et al.[139], yield reductions are expected when temperature surpasses 30 °C, which was not the case with this study (Table 3). So far, the curve of Tmin has never reached the point at which it can cause the Tavg to pass above the optimal range and negatively affect maize yield.

According to the model's long-run estimation, the rising trend in CO_2 emissions had a positive and significant impact on maize yield (Table 4A). Ahsan et al.[140] and Chandio et al.[40] also realized similar yield improvements due to CO_2 emissions. However, it was discovered that the impact of CO_2 emissions on maize yield in the short run was not significant (Table 4A), and this is consistent with Warsame et al.[55] and Anapalli et al.[38] studies, focused on MS. Specifically, every unit increase in CO_2 emissions resulted in a long-term improvement in maize yield of 0.62% (Table 4A). Similar reports of 0.23% and 0.70% yield increases were noted by Asfew and Bedemo[56] and Mahrous[141] where they quantified the positive effects of increased CO_2 emissions. However, Islam et al.[142] estimated that under current climate change scenarios, these CO_2 emissions-driven yield increments might reach 3.5 to 12.8% at the rate of 1.80% every decade[143]. The upsides of elevated CO_2 on maize yield are due to its effects on plant physiology, growth, and biochemistry, through diminished stomatal conductivity and enhanced photosynthetic rates[144–147]. The decreased stomatal conductance reduces water loss thereby increasing water use efficiency, especially in drought-stress conditions[148,149]. The rise in atmospheric CO_2 levels increases the intercellular CO_2 concentration (Ci) and thus, photosynthetic rate (A)[150]. However, maize has a lower carbon saturation point than C3 plants like soybean[151] due to the high affinity (to CO_2) of the key enzyme, phosphoenolpyruvate carboxylase[152,153]. These physiological and biochemical responses of maize to CO_2 indicated that further increases in CO_2 levels may not increase assimilation production[150,151]. Increased CO_2 level have been shown

to benefit other crops[154–157]. However, the response of C4 plants (maize) to elevated CO_2 levels is complex, as it is influenced by various factors such as air temperature, water availability, light intensity, vapor pressures, and nitrogen availability[158,159]. Nevertheless, predicted rise in CO_2 levels by the years 2050 and 2100 may diminish the beneficial effect of CO_2 in row crops, like maize[150,151]. Further research is therefore required to determine the influence of elevated CO_2 in C4 plants at different growth stages[150,152,160,161]

Even though PT is a crucial crop growth factor, the current findings revealed that, at a 1% level of significance, PT patterns were determined to pose a negative and significant effect on maize yields in both the short- and long-term (Table 4A). More specifically, every 1 mm change in PT had reduced maize yield in the short- and long-term, by 0.64% and 2.70%, respectively (Table 4A). These results are consistent with the observations of Rosenzweig et al.[162], Chen et al.[163], and Xiang and Solaymani[58] who also noted the negative effect of the ongoing PT trends on maize yield. A crop yield decline due to prevailing PT trends was also documented in the study by Shammi and Meng[36] in MS. These results are attributable to the excessive PT (1504.44 mm annually) in MS[164]. Excessive PT, in addition to directly or physically harming the crop, results in prolonged wet conditions that lead the soil saturation and are averse to crop development, particularly in conditions of inadequate drainage[165]. This yield-reducing effect of excess moisture is attributable to (i) root growth hindrance impairing plants ability of nutrients and water uptake[166,167], (ii) increased nitrate leaching, leading to nutrient depletion[168], (iii) anoxic conditions in soil, leading to the risk of toxic substances development, diseases, and insect infestation[169], and (iv) delayed planting or harvesting, owing to the difficulty of driving the machinery in wet fields[149,170,171]. On account of the aforementioned factors, the US as a whole suffers a 3% yield loss annually[162,172], and significant yield decline has been seen over the past two decades in various parts of the US *i.e.,* Iowa[173,174]. When the analysis was further scaled down to a monthly level, it was discovered that the most significant month correlated with the MS maize yield was August, and the association was negative (Table 4B). This indicates that the August PT had the most significant negative effect on MS maize, and Eck et al.[82] also deduced similar results documenting increased PT to be detrimental in the latter part of the MGS. This is because the uptake of nitrogen, phosphorus, and potassium in maize plants continues up until the R3-R4 stage in August, when the plant can still transpire to the extent of 0.25–0.30 inches of water, according to Lauer[175], who claimed that by this time, the two (ear and kernel number) of three key yield parameters are determined, but the kernel size/weight is still yet to be determined. Furthermore, low PT is required during the ripening period (August) of maize[96]; nonetheless, the current study found that the MGS month with the highest PT growth rate (2.69 mm/decade) was August (Table 3). However, Rosenzweig et al.[162] had a different perspective on the negative association of August-maize yield, according to them it probably has less to do with plant itself and more primarily linked with the harvesting challenges arising from overly moist conditions, for growers. Delayed harvesting degrades the quality of maize, rendering it unsalvageable, in some instances, due to rotting in the field[82]. Overall, such scenarios of delayed harvesting could lead to a yield loss to the extent of 10%[149].

Pearson's correlation matrix revealed that the RH of any month of MGS had no correlation but DTR of June, July, and August months had negative and strong correlation with the maize yield (Table 4B). These results are consistent with those of Muhammad et al.[176] who found a weak correlation of RH and HA with yields, as well as with that of Lobell[89] who examined the impact of DTR on maize yield.

The coefficient of ECM was determined to be −0.302 (Table 4A), which signifies that every year, 30.20% of the immediate climatic impact cumulatively transfers to form the permanent basis for the long-term effects. A 30.20% is equivalent to the results of Warsame et al.[55] and Jan et al.[44]. The ARDL model estimated the adjusted R^2 value of 0.766, indicating that 76.60% of the total variations in maize yield due to the studied variables are explained by the study model.

Study limitations

Each research has its unique set of limitations, which forms the base for further advancement in the research field. The factors such as maize evapotranspiration, sunshine durations/hours, irrigation intensity, and vapor pressure deficit that could interact to determine the climatic effects for better insights on crop-climate link, were not included in the present study due to data unavailability. Hence, future research is suggested incorporating the aforesaid variables along with the variables considered in the present study for more practicable and accurate estimations.

Concluding remarks

This study demonstrated a markedly rising trend in Tmax, Tmin, and CO_2, with Tmin majorly contributing to the overall warming trend in the MGS of MS. The Tmin progressed at a faster rate (0.14°C decade^{-1}) than the Tmax, causing a considerably lowering trend in the DTR. The month-wise analysis determined the most correlated month for Tmax (June and July), Tmin and DTR (June, July, and August), and PT (August) in significantly impacting maize yield in MS, indicating the varied sensitivity of maize yield to within season variability for different climatic parameters. The crop-climate link assessment revealed a significantly negative effect of Tmax and PT on maize yield in both short and long run, whereas Tmin and CO_2 emissions posed a significantly positive effect on maize yield in long run and no effect in short run. Overall, the study model explained the 76.60% variations in maize yield due to climate change in MS. As shown by the ECM coefficient of the study model, the short-term immediate climatic effects on maize progressively transfer to permanent long-term effects by 30.2% every year, making the crop-climate link more prominent in the long run than in the short run. As the water and nutrient usage efficiencies are climate driven and based on the current findings, it is suggested to reassess the agronomic optimum management strategies in the face of MS crop-climate link. Also, the research efforts need to be intensified to test crop varieties that might be more resistant to elevated Tmax, perform better under delayed planting circumstances, and continue to interact favorably with elevated CO_2 and Tmin scenarios under

the local climatic conditions of the MS. Moreover, it is recommended to test current findings at the field or in controlled settings using the locally prevalent climatic indices with a focus on agronomic optimum management strategies as they react to the climatic variations.

Data availability

The data used in this study is accessed from National Agricultural Statistics Service's repository (USDA-NASS), US Climate Divisional Database (NOAA), PRISM database, and US energy information administration. The online links for these data sources are mentioned in Section "Data" (data) of methodology chapter. However, for more information on data, rs2564@msstate.edu (Ramandeep Kumar Sharma) can be contacted. No separate field study on plants was carried out because all the data used in the study was accessible online.

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REVIEW ARTICLE

A review on co-pyrolysis of agriculture biomass and disposable medical face mask waste for green fuel production: recent advances and thermo-kinetic models

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Abstract The Association of Southeast Asian Nations is blessed with agricultural resources, and with the growing population, it will continue to prosper, which follows the abundance of agricultural biomass. Lignocellulosic biomass attracted researchers' interest in extracting bio-oil from these wastes. However, the resulting bio-oil has low heating values and undesirable physical properties. Hence, co-pyrolysis with plastic or polymer wastes is adopted to improve the yield and quality of the bio-oil. Furthermore, with the spread of the novel coronavirus, the surge of single-use plastic waste such as disposable medical face mask, can potentially set back the previous plastic waste reduction measures. Therefore, studies of existing technologies and techniques are referred in exploring the potential of disposable medical face mask waste as a candidate for co-pyrolysis with biomass. Process parameters, utilisation of catalysts and technologies are key factors in improving and optimising the process to achieve commercial standard of liquid fuel. Catalytic co-pyrolysis involves a series of complex mechanisms, which cannot be explained using simple iso-conversional models. Hence, advanced conversional models are introduced, followed by the evolutionary models and predictive models, which can solve the non-linear catalytic co-pyrolysis reaction kinetics. The outlook and challenges for the topic are discussed in detail.

Keywords biomass, COVID-19 waste, catalyst, pyrolysis, kinetics

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1 Background

1.1 Bioenergy from biomass as a crucial renewable energy source

Association of Southeast Asian Nation (ASEAN) projected its population to grow by 100 million from 2014 to 2025, with an annual growth of 5%, and 4% in energy demand per year. Hence, the association has set the goal to increase its renewable energy share from 9.4% to 23% of the primary energy supply in the ASEAN region [1]. In order to meet the target, member countries has strategise several policies, laws, and regulations [2], as summarised in Table 1, which includes ASEAN member countries and their strategies [3].

Following this, ASEAN countries are known as the top agriculture producers. Hence, there are significant prospects for bioenergy as a strategy to help realise the ASEAN renewable energy generation and consumption goals. For example, Indonesia and Malaysia are the major players in the oil palm industry, followed by Thailand as

Table 1 ASEAN member countries renewable energy policies

Country	Policies/strategies	Ref.
Cambodia	**Energy Sector Development Policy and Rural Electrification Policy, 2007** Rural electrification fund subsidy and investment incentives are provided as support to the policy • Providing reliable, affordable quality supply of electricity to the consumers • Promoting private-owned facilities in the renewable energy sector to instigate competition between the companies • Providing electricity to 70% of the rural households by the year 2030	[4]
India	**The Electricity Act, 2003** • To encourage the co-generation of electricity with renewable sources • Specify the terms and conditions for the determination of tariff, which forms the National Electricity Policy and the Tariff policy **Tariff Policy, 2006** • States that renewable energy shall be distributed with a preferential tariff determined by the appropriate commission • Bidding process within suppliers offering renewable energy from the same source **National Rural Electrification Policies, 2006** • Provision of access of electricity to all households by the year 2009 • Quality and reliable power supply at affordable rates • Providing off grid solutions for rural areas **Integrated Energy Policy Report (Planning Commission), 2006** Recommends a solution to meet the energy demand of India in an integrated process up to 2031–2032	[5]
Indonesia	**Government Rule No. 3 on Supply of Electricity, 2005** To ease the private-own power producers to set up renewable energy plants **Blueprint of National Energy Implementation Program 2005–2025** • To outline plans for energy supply security • To provide guidelines for various sectors involving renewable and non-renewable energies • To provide subsidies to enhance energy efficiency **Presidential Regulation No. 5 on National Energy Policy, 2006** • To set goals to promote diversification of energy sources • To reduce energy consumption by 1% per year as target **Presidential Decree No. 1 on Supply and Use of Biofuels, 2006** Setting targets and guidelines for biofuels utilisation and development **Ministerial Regulation No. 2 on Medium Scale Power Generation from Renewable Energy Sources, 2006** To set pricing guidelines for projects ranging from 1 to 10 MW **Energy Law, 2007** Providing renewable energy developers with investment incentives **Electricity Law, 2010** To encourage private companies to participate in energy supply To provide priority in the utilisation of renewable energy To promote small scaled distributed power generation from renewable sources **Ministerial Regulation No. 4/2012, 2012** To set the Feed-in-Tariff for electricity generated from biomass **Ministerial Regulation No. 27/2014, 2014** • To set goals to increase the renewable energy portion to 23% by the year 2025, and 31% by 2050 • Feed-in-tariffs for renewable energy • To encourage the government and private sectors to utilise biofuels for power generation	[6]
Malaysia	**Five-Fuel Diversification Policy, 2001** To include renewable energy in the energy supply mix of power generation **National Biofuel Policy, 2006** • To reduce dependency on fossil fuels • Providing subsidies to promote the demand for alternate sources of energy **National Renewable Energy Policy and Action Plan, 2010** • Increase the renewable energy contribution in the energy supply mix • Promote growth of the renewable energy sector • Maintaining the renewable energy at an affordable price • Instigate awareness to the community on renewable energy	[7]
Thailand	**Committee on Biofuel Development and Promotion (CBDP), 2008** Government subsidies from the State Oil Fund biodiesel price reduction **Second Alternative Energy Development Plan (2008–2022), 2008** • To increase the proportion of alternative energy to 20% of the national total energy consumption by 2022 • To utilise renewable energy as a substitute for imported oil • To increase energy security of Thailand • Promote integrated green energy utilisation in communities • Enhance the development of alternative energy industry • Research and development of efficient technology to harvest renewable energy	[8]
Vietnam	**Renewable Energy Action Plan, 2001** Government intervention to promote renewable energy **The Law of Electric, 2004** Support electricity generation from renewable sources by providing investment incentives, preferential electricity prices and taxes **Decision 1855/QD-TTg: 27 Dec 2007** • National Energy Development Strategy up to 2020 with outlook to 2050 • To encourage the development of new and renewable energies, bioenergy to meet the socioeconomic requirements • To meet the target of 5% of primary commercial energy by 2020 and 11% by 2050 **Decision No. 177/QD-TTg:20 Nov 2007** • To develop biofuel, as an alternative for fossil fuels • To build a legal framework for biofuel development • To develop materials for biofuel production • To enhance biofuel extraction **National Program for Biofuels Development, 2011** • Develop biofuel to partly replace fossil fuels • Create the legal framework for biofuel development • Develop relevant materials for biofuel production • Develop biofuel extraction technologies	[9]

(*Continued*)

Country	Policies/strategies	Ref.
Myanmar	**Myanmar Energy Master Plan, 2015** • To study the energy demand development from 2014 to 2035 • To set a goal to achieve 15%–20% share of renewable energy in 2020 • To improve the rural renewable energy usage • To achieve 57% hydropower, 5% solar and wind by 2030	[10]
Laos	**The Electric Law, 1997** Setting standards for the administration, production, distribution, transmission and the import and export of electricity **The Power Sector Policy Statement, 2001** • To increase the electricity supply rate to 90% by 2020 • Promotes the public and private partnerships in hydropower development (500 kV grid) **The 8th National Socio-economic Development Plan (NSEDP), 2016–2020** Promotes sustainability and diversification of renewable energy sources **The Renewable Energy Development Strategy** To increase the renewable energy share to 30% and substitute 10% of the transport fuel with biofuels by 2025	[11]
Philippines	**R. A. No. 9367: The Biofuels Act, 2006** Encourage the utilisation of biofuel-blended transport fuels by providing fiscal incentives **R. A. No. 9513: The Renewable Energy Act, 2008** • Enhance the renewable energy development by providing fiscal and non-fiscal incentives • To reduce the country's reliance of fossil fuels • Adopts renewable portfolio standards, feed-in-tariffs, net-metering, and Green Energy Option policy instruments	[12]

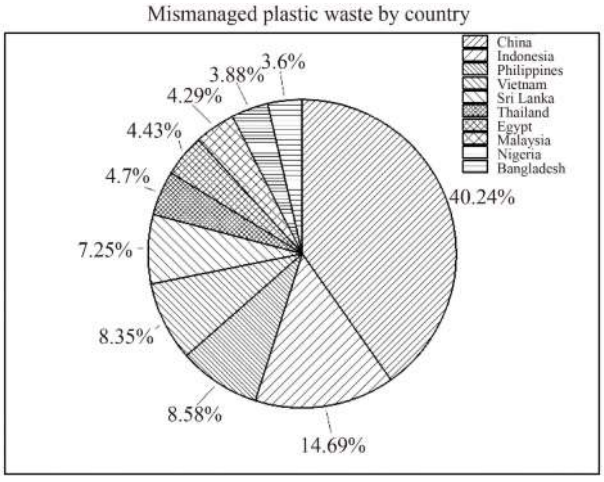

Fig. 1 Mismanaged plastic waste generated by countries. Reprinted with permission from Ref. [24], copyright 2015, American Association for the Advancement of Science.

shown in Fig. 1. In Indonesia, the production volume reached 45.86 million tonnes in 2019 [13]. Meanwhile, Malaysia produced 18.5 million tonnes in the same year [14]. However, the palm oil produced only represents 10% by weight of the total harvest; and the remainder contributed to the oil palm biomass, i.e., oil palm empty fruit bunch (EFB), palm kernel shell (PKS), palm pressed fibres (PPF), and oil palm frond [15]. To accommodate the rising population, food demand such as rice and wheat production in India has grown dramatically. In 1960, rice and wheat production was 34.6 and 11 million tonnes, respectively, and had risen to 118.9 and 107.6 million tonnes respectively in 2019 [16]. The rapid generation of biomass poses sustainability issues and waste management complications. Fortunately, this agriculture biomass is made up of lignocellulosic constituents, which include cellulose (23.3–44.9 wt %), hemicellulose (17.3–34.0 wt %), and lignin (12–53.5 wt %) [17]. Cellulose is a complex polymer of glucose held by β-1,4-glycosidic bonds, intramolecular and intermolecular H-bonds. Hemicellulose is a heterogeneous polysaccharide, consisting of hexoses (i.e., glucose, mannose, galactose, xylose, arabinopyranose, arabinofuranose, and glucuronic acid). Lignin is made up of guaiacyl propane, syringyl propane and *p*-hydrophenyl propane [17,18]. These constituents serve as the basic precursors for the conversion into fuel, fibres, and aromatics [19]. Other properties from the proximate and ultimate analysis are depicted in Table 2, which shows that the biomass contains 50 to 70 wt % of volatile matter. In comparison, the carbon and hydrogen contents are 36–53 and 5.0–7.3 wt %, respectively.

Besides that, plastic or polymer waste generation has increased over the years. According to Geyer et al. [23], the study reports that cumulative plastic waste generation of primary and secondary plastic has reached 6300 million tonnes from 1980 to 2015. Only 12% of these plastic wastes were incinerated, while 9% were recycled. Furthermore, according to Jambeck et al. [24], ASEAN member countries such as Indonesia, Philippines, Vietnam, Thailand, and Malaysia contributed approximately 41% of the mismanaged plastic waste as illustrated in Fig. 1. Moreover, according to Abnisa and Alaba [25], the global composition of plastic wastes comprises of 26.67% low density polyethylene (LDPE), 25.33% polypropylene (PP), 18.67% high density polyethylene (HDPE), 14.67% polyethylene terephthalate (PET), 8% polystyrene (PS), and 6.67% polyvinyl chloride (PVC). Furthermore, with the rapid rise of confirmed cases of the novel coronavirus disease (COVID-19), the need for personal protective equipment (PPE) is high, resulting in the rapid generation of COVID-19 related wastes, exacerbating the current plastic waste management issue. According to Liang et al. [26], there are two categories of COVID-19 related wastes which are (1) wastes generated

Table 2 Proximate and ultimate analysis of different agriculture biomasses [20–22]

Sample	PKS	PPF	EFB	Rice husk	Rice straw (RS)	Bagasse
Proximate analysis/(wt %)						
Moisture	5.73	6.56	8.75	4.50	–	–
Ash	2.21	5.33	3.02	12.40	13.60	6.50
Volatile matter	73.74	75.99	79.67	58.60	70.10	72.70
Fixed carbon	18.37	12.39	8.65	24.40	16.30	20.80
Ultimate analysis/(wt %)						
C	53.78	50.27	48.79	43.20	37.10	36.30
H	7.20	7.07	7.33	5.00	5.20	5.80
S	0.51	0.63	0.68	0.00	0.10	0.00
N	0.00	0.42	0.00	0.30	0.50	0.30
O	36.3	36.28	40.18	51.4	43.5	51.10

from within hospitals or healthcare facilities, which are considered medical wastes and are collected and disposed of with appropriate measures (i.e., identification, collection, separation, storage, transportation, treatment, and disposal) [26], and (2) the wastes generated outside those facilities, which include disposable medical face masks (DMFM) and gloves. These wastes do not have proper waste management and are often treated as municipal solid, and plastics wastes. Besides that, according to the World Health Organisation (WHO) [27], the demand for these PPE, i.e., DMFM, and gloves, is expected to rise 20% by the year 2025. If these wastes are not managed properly, it will lead to major environmental complications. In some parts of the ASEAN region (i.e., Cambodia, Philippines, India, and Indonesia), poor waste management issues such as landfills and illegal dumping were present even before COVID-19. These uncontrollable landfills would escalate into space limitations and release toxic pollutants to the environment [28]. Moreover, the random disposal of these wastes could also lead to microplastic pollution, accumulating in the food chain, especially in aquatic life [29].

1.2 Biomass and polymer waste conversion pathways: pyrolysis

Therefore, strategies to recover energy from these wastes are keys to minimize the waste accumulation and their impacts to the environment. To convert these high-energy feedstocks into valuable fuel, there are two main pathways to convert the lignocellulosic biomass and plastic wastes into biofuels or green fuels, i.e., bio-chemical conversion and thermochemical conversion. In bio-chemical conversion, the larger and complex compounds are broken down into simpler molecules, with bacteria and enzymes. However, this method has limited feedstock options, and is not suitable to convert synthetic polymers like plastic wastes [30]. Besides that, thermochemical conversion includes low-temperature carbonisation, intermediate-temperature pyrolysis, and high-temperature gasification. Among these thermochemical processes, pyrolysis represents a promising technology in terms of high fuel-to-feed ratios [31]. In addition, the pyrolysis process is favoured as the process that can be carried out at atmospheric pressure and faster conversion rates (<1 s) [32]. Moreover, the pyrolysis process is compatible with a wide variety of feedstocks aside from lignocellulosic biomass, i.e., plastics, and waste tires [33–36]. The pyrolysis process involves-production of biofuel in the form of bio-oil, as well as producing valuable bio-chemicals such as alcohols, aldehydes, ketones, acids, furans, anhydrosugars, and phenols from biomass [37]. Fast pyrolysis yields the highest amount of bio-oil (65–75 wt %), while slow pyrolysis produces less bio-oil (20–50 wt %), with a larger proportion of bio-gas (20–50 wt %) and biochar (25–35 wt %) [38]. A detailed information on the different pyrolysis modes can be found in these references [38–43].

This paper focuses on the issues of the growing generation of biomass in ASEAN region, as well as the single-use plastics (i.e., DMFM) generated due to the COVID-19 pandemic. Following this, this review outlines the potential of co-pyrolysis of the biomass with plastic wastes as a technique to produce value-added bio-oil. Besides that, this review also looks into the technologies, (i.e., catalyst selection) and technical aspects (i.e., pyrolysis parameters) of the co-pyrolysis process. In addition, the kinetic models, and the advancements to describe the catalytic co-pyrolysis of biomass and plastic wastes are also outlined. Finally, the outlook detailing the significance and the limitations of the co-pyrolysis technique is discussed.

2 Bibliometric analysis

Bibliometric analysis is defined as the analysis of scientific publications using statistical methods to provide an outline of the research area [44]. Several publications have adopted this method in research areas of bio-diesels [45], municipal solid waste management [44], invest-

ments [46], and even COVID-19 [47]. This method of analysis provides a systematic way to sort and analyse a great number of publications, in terms of citations, co-citations, author keywords, and countries.

In this project, the bibliometric analysis of the field of pyrolysis of biomass was conducted in VOSviewer1.6.11. The utilisation of the software has been widely employed in this study, providing a visualisation of the relationships between publications in a research area or topic. The online publication database platform, Scopus, was utilised in the collection of the database for this study. The search phrase and Boolean Operators for this study were "pyrolysis AND biomass AND plastic AND bio-oil OR oil palm OR catalyst", the publication year was limited from 2019 to 2023, and limited to journal articles only. A total of 1448 publications were fitted into VOSviewer to analyse the co-occurrence of author keywords more than 20 times and are visualised in Fig. 2. The top-ranked link strength keywords, excluding the search phrases, include catalytic pyrolysis, co-pyrolysis, biochar, oxygen reduction reaction, and hydrogen. Based on this study, the current research trend involves around catalytic pyrolysis or co-pyrolysis, and focuses on the oxygen reduction, hydrogen and biochar formation from the process. Furthermore, another analysis of the bibliographic coupling of countries was carried out and the results were visualised in Fig. 3. The result suggests that China, United States, South Korea, Malaysia, and Australia are the active countries involved in this research area.

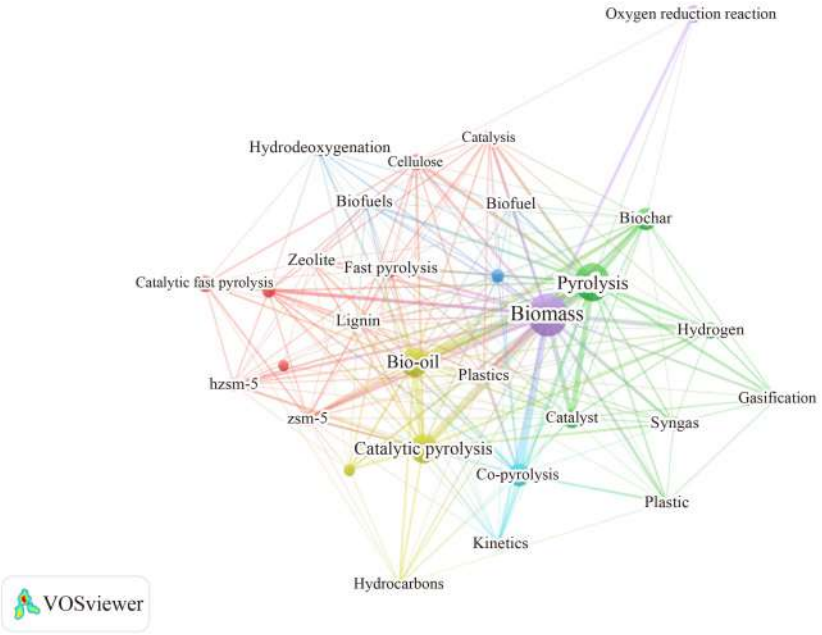

Fig. 2 Co-occurrence of author's keywords > 20 times by publication year.

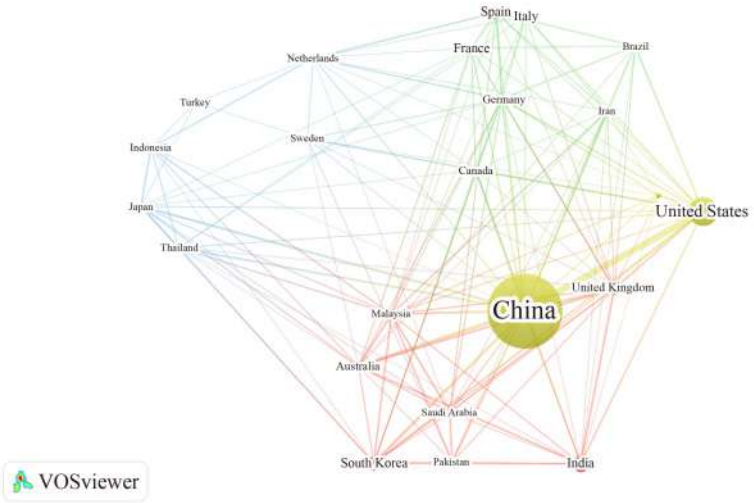

Fig. 3 Bibliographic coupling of countries by year.

3 Pyrolysis technologies/techniques for bio-oil production

Initially, most of the research studies focus on mono-component such as biomass [20,48–54] or plastic waste [55–60] in the pyrolysis process for bio-oil production. However, the pyrolysis of lignocellulosic biomass produces low quality bio-oil and yield [61]. Biomass-derived pyrolysis oil is high in oxygen content, corrosive in nature, and thermally unstable. Bio-oil generally requires upgradation using a hydrogen source and a catalyst, which makes the process complicated and expensive [37]. For plastic pyrolysis, the volatile products contain harmful compounds, i.e., polycyclic aromatic hydrocarbons (PAHs) [62–64]. PAH is a macromolecular aromatic compound with carcinogenic and mutagenic characteristics that pose health concerns upon exposure [65]. Hence, there is a growing interest in improving the pyrolysis process to produce bio-oil with enhanced properties, i.e., co-pyrolysis of two or more feedstock, and the utilisation of catalysts for product upgrading.

3.1 Mechanisms of co-pyrolysis with polymers

Hence, it is crucial to understand the reaction mechanism of co-pyrolysis of biomass and plastic wastes. Several studies have explored the co-pyrolysis of biomass with polymer wastes, i.e., RS and sugarcane bagasse with PP, and PS [34]; corn stover, ipil, and narra, with HDPE, LDPE and PP [35]; RS with waste tires [36]; sawdust with LDPE [66]. These studies show that the co-pyrolysis technique is promising in improving the bio-oil quality and calorific value, reducing energy costs by lowering the activation energy. According to Lin et al. [67], the widely accepted mechanism of co-pyrolysis of biomass with plastics can be summarised in a two-step mechanism: (1) the free radicals generated from the pyrolysis of biomass initiate the β-scission of the polymers, inhibiting the intermolecular and intramolecular H transfer, producing aliphatic hydrocarbons and reduced alkadienes; (2) the H transfers from the polymers reacting with the biomass-derived radicals to form stable compounds. This mechanism allows an increase in the decomposition rate of the biomass, greatly reducing the char yield as reported by Önal et al. [68]. The addition of a hydrogen-rich plastic waste to biomass influenced the energy recovery efficiency of bio-oil by affecting the real-time power output, reaction time, and changes in the bio-oil composition [69]. Besides that, the biomass decomposes first at a lower temperature forming free radicals, i.e., OH radicals. These radicals react with the pyrolysis products of plastic, larger molecular weight organics (C_{12}) were formed with the co-pyrolysis of biomass and LDPE [70]. According to Navarro et al. [34], this mechanism reduces the selectivity for the secondary reaction to occur, reducing the char yield (i.e., 8.6 and 10 wt % reduction of char with the co-pyrolysis of B and PS, B and PP, respectively). Besides that, according to a study by Ojha et al. [71], the formation of C_8–C_{20} alcohols was observed, which was explained by the reaction of hydrocarbon free radicals from PP, with water from the dehydration reaction from cellulose. According to Uzoejinwa et al. [72], synthetic polymers are derived from petroleum products with high carbon and hydrogen contents, low oxygen content, and contains high calorific values. Hence, making it suitable potential as a co-feedstock for the biomass pyrolysis. Furthermore, these polymer wastes also showed similar properties of high volatile matter, higher heating value (HHV) and lower heating value (LHV) than biomass, as observed in Table 3.

3.2 Pyrolysis reaction parameters that influence the bio-oil yield

During pyrolysis, multiple factors affect the outcome of the process, which are, reactor temperature, heating rate, feedstock particle size, and residence time. Studies on these parameters are crucial to improve the pyrolysis process in terms of bio-oil product yield and quality. Generally, the operating parameters are adjusted, to impede the secondary tar cracking reactions, which reduces the bio-oil yield.

3.2.1 Pyrolysis temperature

The role of temperature is to provide sufficient thermal energy for the decomposition of the biomass. It is important to note that for the main constituents of biomass, cellulose, hemicellulose, and lignin, their temperature degradation ranges are 225–325, 325–375, and 250–500 °C, respectively. Hence, an optimal temperature of 500 °C is sufficient to encompass these temperature ranges. Nevertheless, the optimal temperature differs with the compositions of varying feedstock [74]. Furthermore, according to Dai et al. [75], bio-oil yield peaks at the

Table 3 Proximate and ultimate analysis of polymers [22,34,60,73]

Sample	PP	PS	LDPE	HDPE	Waste tires
Proximate analysis/(wt %)					
Moisture	0.20	–	–	0.00	1.10
Ash	0.10	0.00	–	0.00	8.10
Volatile matter	99.80	99.50	99.98	100.00	62.50
Fixed carbon	0.00	0.50	0.02	0.00	28.20
Ultimate analysis/(wt %)					
C	85.40	89.50	85.47	85.34	84.60
H	14.50	8.50	14.21	12.22	7.70
S	0.00	0.00	0.11	0.00	1.40
N	0.00	0.00	0.08	0.00	0.40
O	0.00	2.00	0.13	2.44	4.30
HHV/(MJ·kg^{-1})	46.00	40.10	–	46.40	36.80
LHV/(MJ·kg^{-1})	43.10	–	–	43.10	35.10

temperature range of 450–550 °C; a further increase of temperature (> 600 °C), the bio-oil yield reduces, corresponding to an increase in non-condensable gas, or biogas. Moreover, a higher temperature (530–830 °C) promotes the reduction of complex compounds (i.e., acetaldehyde, methanol, propanol, and acetone), while increasing stable compounds (benzene, naphthalene, cresols, and phenols). For the case of polymer wastes, the degradation temperature ranges generally overlap or are higher than biomass, which varies between types of polymers. According to Miandad et al. [33], PP showed a single-stage degradation, which starts at a lower temperature of 240 °C with the maximum degradation at 425 °C, PS also showed a single-stage degradation but starts at a higher temperature of 330 °C, with the maximum degradation at 470 °C. While polyethylene (PE) exhibits a two-stage degradation, the first stage starts at the temperature of 270 °C and reaches 400 °C with a conversion rate of 12%, which followed by the second stage degradation starting at 400 °C, with the maximum conversion rate of 95% at 480 °C. Hence, these differences in thermal decomposition behaviours must be considered for the co-pyrolysis of biomass and polymers. According to Salvilla et al. [35], the study studied the effect of co-pyrolysis of corn stover with different polymers, i.e., LDPE, PP, and HDPE. Thermogravimetry analysis (TGA) experiments of the biomass-plastic blends result in a two-stage decomposition. The first stage involves the degradation of hemicellulose, and cellulose of the corn stover, while the second stage degradation overlaps with the decomposition of lignin. The results from this study conclude that the biomass and plastic blends exhibit the most synergistic effect occurs at temperature near 500 °C, i.e., corn stover and PP blend (5:3), and corn stover and LDPE blend (5:3) observed the greatest decomposition rate between 8% and 10% per minute respectively between the temperature ranges of 480–505 °C.

3.2.2 Heating rate

The heating rate is another important parameter that could determine the product distribution of the biofuels. According to Akhtar and Saidina Amin [31], fast heating rates cause rapid fragmentations of biomass and produces more bio-oil yield. This is possible as at higher heating rates (1000 °C·min^{-1}), there is short amount of time for the secondary reactions (i.e., tar cracking and repolymerisation). However, once the heat and mass transfer limitations have been overcome, higher heating rates would not increase the bio-oil yield further. Besides that, heating rates also affect the quality of the bio-oil, at lower heating rates, the water content of the bio-oil increases, as it impedes the dehydration reaction. It is also observed that at low heating rates (< 15 °C·min^{-1}) the bio-oil components have a higher weight range of 500–1000 Da, while increasing the heating rate to 15 °C·min^{-1}, it significantly reduces the weight to 200–500 Da. However, continuing to increase the heating rate does not reduce the weight further [75]. In the case of polymer waste, the study found that LDPE, PP, and PVC, the thermogravimetry or derivative thermogravimetry curves shifted to the higher temperatures when the heating rate was increased. This phenomenon was explained by the thermal lag, due to the increased thermal gradient between the furnace temperature and the sample. Hence, the lower 100 °C·min^{-1} heating rate favoured the degradation of the plastic wastes [60].

3.2.3 Particle size

To reduce heat transfer limitations caused by the poor heat conductivity of biomass, feedstock particle size or shape is another important criterion for bio-oil production. Larger particles (> 0.5 mm) tend to have poor heat transfer to the inner surfaces of the feedstock particle, this will lead to a lower yield of volatiles associated with the great temperature differences between the inner and outer surfaces of the feedstock particle. However, it is documented further increase in particle size (> 1 mm) does not have any effect on the bio-oil yield, which indicates minor impact of the internal heat or mass transfer to the process [76]. It was also reported that larger particle size, results in lower heat transfer to the feedstock [31,75]. For the pyrolysis of bamboo biomass with particle size, 0.45–0.75 mm, the bio-oil peaked at 54.03 wt %, while for smaller particle size 0.25–0.45 mm lowers the bio-oil yield to 50.85 wt % but increases biogas yield from 18.42 to 23.46 wt % [77]. Larger particle size of 0.8–1.2 mm, on the other hand, also lowered bio-oil yield of 51.61 wt %, with increased biogas and biochar yield of 20.62 and 27.74 wt %, respectively.

3.2.4 Residence time

Likewise, since the pyrolysis vapour is susceptible to secondary reactions, it is important to note that, the vapour residence time must be kept short to maximise the bio-oil yield. However, at very short residence times, the heat transfer limitations may restrict the feedstock from undergoing complete fragmentation [32,74,75]. Hence, the parameter is restricted by the characteristic of the feedstock itself. Instead, optimisation of the vapour residence time is a more feasible direction, i.e., feedstock particle size, heating rate, and design of the reactor and heater configuration to maximise the heat transfer [31].

3.3 The role of catalysts in the pyrolysis process

Catalysts play an important role in enhancing the quality of the bio-oil. This section categorised the existing catalysts employed in the pyrolysis process into three

main groups, commercial zeolite catalysts, metal-based catalysts, and renewable waste catalysts.

3.3.1 Commercial zeolite or acid catalyst

The commercial zeolite catalysts, i.e., ZSM-5, HZSM-5, MCM-41, zeolite Y, SBA-15, and zeolite BEA are the commonly utilised catalysts for the pyrolysis of biomass [78]. These catalysts have the active sites of the catalysts and reduce the dissociation energy of C–O, C=O, and –OH functional group, which allow the ability to remove oxygen atoms from the bio-oil via dehydration, decarboxylation, decarbonylation reactions [42,79]. Besides that, according to Ratnasari et al. [80], the key attributes of the zeolite as a suitable catalyst are the micropores (0.4–1.0 nm) or mesopores (1.5–30 nm) sizes. In a study on MCM-41, a zeolite catalyst with a mesoporous structure; the bigger pores allow hydrocarbons with higher molecular weight to enter the active sites, produce less oxygenates, and yield less aromatics. While smaller pore sized zeolites, such as ZSM-5 and Y-zeolite favour the production of aromatics. However, due to its smaller pore size, it is more likely to cause coking on the surface of these zeolites, thereby deactivating them. Therefore, studies have incorporated hierarchical catalyst structure to maximise the conversion performance [78,81]. Besides that, the acidity of the zeolites refers to the Si/Al ratio of the zeolite, it is a direct representation of the Brønsted acid (–OH group) and Lewis acid (Al sources in the Al_2O_3/SiO_2) sites available [74]. Comparing with zeolites, the silicalite catalyst with the same pore size but without acidity produces less aromatics and increases char formation [32]. Besides that, a study on the catalytic co-pyrolysis of RS and B with plastic wastes concluded that HZSM-5 promoted the deoxygenation, cleavage of the aromatic rings, reforming, isomerisation and Diels−Alder reaction of the bio-oil [22]. Hence, product upgradation was achieved, and thereby producing valuable compounds, such as aromatics (i.e., styrene, ethylbenzene, *o*-xylene, and trimethyl-benzene) and aliphatic hydrocarbons (i.e., 2,4-dimethyl heptane). Zhao et al. [82] found that, with the bamboo to PP ratio of 1:2 over HZSM-5, high bio-oil yield of 61.62 wt % can be achieved, which is higher compared to that obtained for single feedstock bamboo pyrolysis of 29.91 wt %. Besides that, the aromatic and naphthenic hydrocarbons in the bio-oil were improved, which was in agreement with the study by Suriapparao et al. [22], where with the addition of a catalyst, the biomass−plastic mixture has a lower selectivity for oxygenates, while an increase in aliphatic and aromatic hydrocarbons were observed. The findings summarising the commercial acid catalysts utilised in literature can be found in Table 4.

3.3.2 Commercial metal-based catalyst/support

The metal-based catalysts in the catalytic pyrolysis of biomass majority refers to the metal oxides, alkali earth metals, metal salts, and transition metals. Metal oxides are prominent catalysts in this case, i.e., the basic MgO, CaO, and the acidic ZnO in the study of the pyrolysis of RS. The catalytic behaviour of MgO is similar to ZSM-5, as it favours the ketonization and aldol condensation reactions, which help to reduce oxygenates from the bio-oil [75]. According to Cao et al. [83], MgO has high ionic properties, which inhibits the repolymerisation reaction, hence greatly reduces the biochar formation while increasing the bio-oil yield. Furthermore, CaO was determined to have unique properties, as it behaves differently at different mass ratio incorporated in the feedstock, at less than 0.2 mass ratios; the CaO is a reactant, that reacts with the carboxyl groups to produce ketones. Carboxyl groups are undesirable bio-oil products due to their acidity, i.e., acetic acid. At 0.2 to 0.4 mass

Table 4 Acid zeolite catalyst application in the pyrolysis process examples

Biomass	Catalyst	Bio-oil yield/(wt %)	Reactor	Scale, feed weight/g	Ref.
RS	HZSM-5	21.50	Microwave pyrolysis	200–800	[22]
Bagasse		22.40			
PP		74.20			
PS		92.30			
Baggase: PS		43.80			
B:PP		35.70			
RS:PS		31.20			
RS:PP		24.50			
RS	ZSM-5	47.40	Fixed bed reactor	10	[83]
	Y zeolite	55.20			
	Mordenite	49.10			
	SBA-15	37.30			
Rice husk and WGPF	HZSM-5/MCM41	67.90% hydrocarbon relative content	Tubular reactor	0.001	[81]
	HZSM5	60.20% hydrocarbon relative content			
Seaweed biomass	ZSM-5	51.48	Hydro-pyrolysis	10	[32]
	MCM-41	41.84			
Bamboo	HZSM-5	49.14	Bubbling fluidised bed	100 $g \cdot h^{-1}$	[77]

ratio, CaO exhibits absorbent properties, absorbing CO_2 to $CaCO_3$, which contributes to the mass increase in the char yield. A further increase of CaO (> 0.4 mass ratio), the catalytic effect dominates, reducing the ester content in the bio-oil into simpler hydrocarbons and H_2 [84]. Besides that, while ZnO has less deoxygenation properties compared to CaO and MgO, it does not increase biochar yield [32,75,85]. On the other hand, studies have also found that metal salts have effectively improved the bio-oil yield. In a study of metal salt catalysts, $MgCl_2$ produced the maximum bio-oil yield of 48.4 wt % [83], comparing to the transition metal salt $FeCl_3$, which has a lower bio-oil yield of 32.2 wt %. According to the study, the ionic behaviour of the alkali earth metal salt, $MgCl_2$ minimises the repolymerisation reaction compared to the partial covalent transition metal salts. In recent studies of the plastic pyrolysis process, the metal catalysts such as carbon-supported platinum (Pt/C), and palladium (Pd/C) were studied in the pyrolysis of PET plastic. The study aims to reduce the polycyclic compounds and biphenyls which are harmful compounds to the environment and public health. The study concludes that Pt/C aided in the reduction of polyclyclic compounds such as 2-napthalenecarboxylic acid by 102% at 800 °C, and reduction of biphenyls such as biphenyl-4-carboxylic acid by 27% at 700 °C [86]. Furthermore, metal oxides have been employed to study the co-pyrolysis process of PP with poplar wood (i.e., ZnO, CaO, MgO, and Fe_2O_3). The researchers found that CaO has the best deoxygenation results, removing carboxylic acids and phenols from the final products. It also increases cyclopentanones and alkenes compositions, but has reduced total volatile compounds, due to its strong basicity to cause coking on the catalyst surface. ZnO has the highest alkene yield, and increased ketone and phenols yields, and reduced carboxylic acid but has the weakest deoxygenation activities among all four catalysts. MgO behaves similarly to CaO, but has weaker deoxygenation properties, as it is less basic than CaO. Moreover, in the presence of the Fe_2O_3 catalyst, formation of aromatics such as *p*-xylene and 2-methyl-1-butenylbenzene were formed [87]. Following this, the studies of metal-based catalysts are summarised in Table 5, CaO is widely utilised in many studies due to its abundance and low cost, which can be found in renewable sources such as limestone and eggshells [88], and the niche in the utilisation of metal catalysts in the co-pyrolysis process.

3.3.3 Renewable waste catalyst

Renewable waste catalysts received much attention as an economic and sustainable alternative to commercial catalysts, i.e., red mud, ash catalysts, activated carbon, biochar derived catalyst, and palm oil sludge [90–94]. Red mud has attained much research interest as it has the potential to replace commercial catalyst. It is an alkaline

Table 5 Metal based catalyst application in the pyrolysis process examples

Biomass	Catalyst	Category	Bio-oil yield/(wt %)	Reactor	Scale, feed weight/g	Ref.
EFBF	CaO	Basic metal oxide	39.90 (5 wt % CaO); 40.40 (10 wt % CaO)	Fixed bed reactor	15	[85]
	MgO	Basic metal oxide	39.30 (5 wt % MgO); 42.30 (10 wt % MgO)			
	ZnO	Acidic metal oxide	44.70 (5 wt % ZnO); 42.20 (10 wt % ZnO)			
Cotton stalk	CaO	Basic metal oxide	50.00	Fixed bed reactor	–	[84]
RS	$MgCl_2$	Metal salt oxide	48.40	Fixed bed reactor	10	[83]
	$FeCl_3$	Metal salt	32.20			
	$CuCl_2$	Metal salt	41.50			
	$MnCl_2$	Metal salt	45.30			
	CaO	Basic metal oxide	38.70			
	$CaCO_3$	Basic metal oxide	30.50			
	MgO	Basic metal oxide	52.10			
	$MgCO_3$	Basic metal oxide	42.40			
	CeO_2	Acidic metal oxide	52.30			
	ZnO	Acidic metal oxide	46.20			
	ZrO_2	Acidic metal oxide	48.30			
	TiO_2	Acidic metal oxide	48.20			
EFB	CaO	Basic metal oxide	58.49	Fixed bed reactor	50	[89]
PET	Pt	Metal catalyst	–	Tube furnace	1	[86]
	Pd					
PP-poplar wood composite	ZnO	Acidic metal oxide	–	Pyrolysis-gas chromatography/mass spectrometry	0.5 mg	[87]
	CaO	Basic metal oxide				
	Fe_2O_3	Acidic metal oxide				
	MgO	Basic metal oxide				

solid by-product from the Bayer process in alumina production. According to Ly et al. [77], the components within the red mud include a great amount of metal oxides, i.e., MgO, CaO, SiO_2, Fe_2O_3, Al_2O_3, and TiO_2. From the study, red mud has a comparable bio-oil yield than HZSM-5 at temperature of 475 °C and residence time of 1.8 s. Upon characterisation of the bio-oil produced from red mud, the catalyst promoted the depolymerisation of cellulose and hemicellulose to produce furan derivatives. Besides that, the formation of saturated phenols in the bio-oil indicates red mud favours the demethylation and demethoxylation reactions. Furthermore, researchers have also studied the catalytic effect of the pyrolysis biochar. According to Dong et al. [95], the experiment on the catalytic pyrolysis of bamboo waste with different ratios of biochar, concluded that, the bio-oil had been upgraded; simpler C_2–C_6 compounds have been greatly increased with reduction in the heavy C_7–C_{11} compounds. Moreover, Chen et al. [96] proposed upgrading the biochar from the pyrolysis process such as N-doped biochar, found high yields of bio-oil (61.0–63.0 wt %) were obtainable. A study on the Fe incorporated activated carbon reduces the bio-oil yield to achieve increased phenols 60.85–86.98 wt % of the bio-oil [97]. For the pyrolysis of plastic wastes, most research utilises the low-cost fly ash and naturally occurring kaolin as renewable catalyst sources [98–100]. Furthermore, in the case of co-pyrolysis, renewable waste catalysts such as Ni-doped biochar from waste pine sawdust, and activated carbon made from coconut husks were utilized [101,102]. The summary of renewable waste catalysts is depicted in Table 6, shows that renewable waste in the literature has much lower bio-oil yields or has a higher selectivity to syngas production than commercial catalysts.

4 Kinetic analysis

Kinetic analysis is an important aspect in describing the chemical kinetics of the pyrolysis process in the form of mathematical models. Traditionally modelling the chemical kinetics of biomass pyrolysis considers cellulose, hemicellulose, and lignin, based on the TGA experimental data. These kinetic models include the iso-conversional models, the Vyazovkin method, distributed activation energy model (DAEM), and the utilisation of predictive tools, i.e., artificial neural network (ANN).

4.1 Iso-conversional models

Iso-conversional method is the simplest form of kinetic model to explain the conversion of biomass to volatiles and biochar as a one-step first-order reaction. Examples of the iso-conversional method include the Kissinger–Akahira–Sunose (KAS), Flynn–Wall–Ozawa (FWO), and Starink's method, which are integral methods ($g(a)$). In contrast, the Friedman method is an example of a differential method ($f(a)$) [104]. In this paper, Friedman and Starink's methods are chosen to demonstrate the difference between the differential and integral versions of the iso-conversional method.

4.1.1 Friedman method

Friedman method is based on the differential method as the following expression in Eq. (1). This method requires the information on the conversion rate $\frac{d\alpha}{dt}$, and T. The kinetic plots between $\ln\left(\frac{d\alpha}{dt}\right)$ and $\frac{1}{T}$ produce the slope of

Table 6 Renewable waste catalyst for pyrolysis process examples

Biomass	Catalyst	Bio-oil yield/wt %	Reactor	Scale, feed weight/g	Ref.
Bamboo	Biochar	20.20 (5 wt % biochar) 18.70 (10 wt % biochar) 16.34 (20 wt % biochar)	Microwave pyrolysis	50	[95]
Bamboo	N-doped biochar	61.00 (10 wt % biochar) 63.00 (30 wt % biochar) 62.00 (50 wt % biochar)	Fixed bed reactor	3	[96]
PKS	Fe/activated carbon	7.96	Microwave pyrolysis	10	[97]
Rice husk	Rice hull ash	–	Fixed bed reactor	0.0055	[92]
Rice husk	Coal bottom ash	–	Fixed bed reactor	0.0055	[93]
PKS	Red mud	37.37–39.95	Fixed bed reactor	2	[103]
Bamboo	Red mud	50.34	Bubbling fluidised bed	100 $g \cdot h^{-1}$	[77]
EFB	Palm oil sludge	–	Fixed bed reactor	15	[90]
LDPE	Calcinated fly ash (900 °C) Calcinated fly ash (800 °C) Natural fly ash	76.22–80.02 70.96–71.36 68.20–71.70	Semi batch reactor	50	[98]
HDPE (plastic tub pieces)	Fly ash (10 wt %)	50.84	Lab scale pyrolyzer unit	1 kg	[100]
LDPE	Kaolin (1350 mesh)	64.66% aliphatics, 93.91% hydrocarbons, 30.07% H_2	Quartz furnace tube	100	[99]
Pine sawdust and PE (50 wt %)	Ni-pine sawdust biochar	70.40 wt % (gas yield)	Fixed bed reactor	1	[101]
Corn stalk-HDPE mixture	Activated carbon	–	Tubular reactor	2	[102]

$\frac{E}{R \cdot T}$ and the intercept of $\ln[Af(\alpha)^n]$. The benefit of this model is that it makes no approximations, and can be adopted in any temperature settings [105],

$$\ln\left(\frac{\mathrm{d}\alpha}{\mathrm{d}t}\right) = \ln[Af(\alpha)^n] - \frac{E}{R \cdot T}, \quad (1)$$

where $f(\alpha)$, T, A, R, E are the differential form of the kinetic dependence function, absolute temperature (K), exponential factor (s^{-1}), universal gas constant (8.314 $J \cdot mol^{-1} \cdot K^{-1}$), activation energy ($kJ \cdot mol^{-1}$).

4.1.2 Starink's method

Starink's method is an extension of the Coats–Redfern equation (Eq. (2)), which is similar to the FWO method, an integral method for estimating kinetic parameters [105]. Since $2RT/E \leq 1$, and has minimal variation with T, results in Eq. (3),

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^2}\right) = \ln\left[\frac{A \cdot R}{E}\left(1 - \frac{2R \cdot T}{E}\right)\right] - \frac{E}{R \cdot T}, \quad (2)$$

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^2}\right) \cong \ln\left(\frac{A \cdot R}{E}\right) - \frac{E}{R \cdot T}, \quad (3)$$

where β, $g(\alpha)$ are the heating rate ($°C \cdot min^{-1}$), and the integral form of the kinetic dependence function. The generalised form Eq. (4) is

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^m}\right) = B - C\left(\frac{E}{R \cdot T}\right). \quad (4)$$

Starink's equation utilises the constants, where m = 1.92, $B = \ln(AR/E) + 3.7545411 - 1.92\ln E$, and C = 1.0008, which can be rewritten as Eq. (5),

$$\ln\left(\frac{\beta}{T^{1.92}}\right) = C_s - 1.0008\left(\frac{E}{R \cdot T}\right), \quad (5)$$

where C_s is the constant. This method is a simple direct method to obtain the expression E/R from the slopes by plotting $\ln\left(\frac{\beta}{T^{1.92}}\right)$ vs. $1/T$. Starink's method is widely employed as a comparison against other iso-conversional methods [48,106]. However, these methods are flawed, as proposed, with an addition of a secondary feedstock and the utilisation of a catalyst, the reaction mechanisms become much more complex [107]. Hence, a modified iso-conversional method is introduced, the Vyazovkin method.

4.2 Vyazovkin method

The iso-conversional methods assume a reaction ideally has a constant value of E_α. This assumption is the main source of errors, which explains the differences obtained from different iso-conversional methods [105]. Hence, to overcome these drawbacks, an advanced alternative non-linear iso-conversional Vyazovkin method is proposed. This method assumes the reaction is independent of the heating rate, and accounts for the variation of E in the computation of the temperature integral, $I(E_\alpha, T_\alpha)$ from Eq. (6). The E_α, which is the effective activation energy ($kJ \cdot mol^{-1}$) is obtained from the minimisation of the function $\varnothing(E_\alpha)$ from Eq. (7),

$$I(E_\alpha, T_\alpha) = \int_0^{T_\alpha}\left(-\frac{E_\alpha}{R \cdot T}\right)\mathrm{d}T = \frac{E_\alpha}{R}p(x), \quad (6)$$

$$\varnothing(E_\alpha) = \sum_i^n \sum_{j=i}^n \left(\frac{I(E_\alpha, T_{\alpha,i})}{I(E_\alpha, T_{\alpha,j})} \cdot \frac{\beta_j}{\beta_i}\right), \quad (7)$$

where n, E_α, T_α are the number of heating rates in the experiment, activation energy and temperature for each α, while i and j represent the heating rates corresponding to n. For $p(x)$, it is the approximation equation obtained from using Yang equation, Eq. (8):

$$p(x) = \frac{\exp(-x)}{x} \cdot \frac{x^3 + 18x^2 + 88x + 96}{x^4 + 20x^3 + 120x^2 + 240x + 120}, \quad (8)$$

where x is the simplified expression of E/RT. Hence, due to its complex structure, this model requires a numerical approach to solve for the kinetic parameters. Recent studies have started adopting this method to compute the kinetic parameters [48,54].

4.3 Distributed activation energy model

In a complex process such as co-pyrolysis, the E_α would not be constant. Instead, it varies as an indication of a much more complex reaction in place, which is unable to explain over a single-step kinetic model. The DAEM is an accurate and versatile model to represent complex pyrolysis processes. It is the best mathematical method to show the physical and chemical heterogeneity of biomass during a devolatisation process [34]. According to Hameed et al. [107], DAEM takes into consideration of the decomposition of species over a large number of independent parallel reactions with different activation energies, represented by a continuous distribution function (i.e., Gaussian distribution, $f(E)$), Eq. (9):

$$f(E) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{E - E_M}{\sigma}\right)^2\right], \quad (9)$$

where σ, E_M are the standard deviation and the mean activation energy, respectively. Furthermore, studies have simplified the DAEM based on the assumption that the solid feedstock is a complex mixture of compounds. During the pyrolysis process, a great number of independent consecutive or simultaneous, irreversible reactions take place, each characterised by its corresponding activation energies and pre-exponential factor, given by Eq. (10):

$$1 - \alpha = \int_0^\infty \exp\left(-A\int_0^t \exp\left(\frac{E}{RT}\right)\mathrm{d}t\right) \cdot f(E)\,\mathrm{d}E = \varnothing, \quad (10)$$

where, according to Cano–Pleite et al. [108], $\varnothing$ = 0.58,

which can be simplified as Eq. (11):

$$\ln\left(\frac{\beta}{T}\right) = \ln\left(\frac{A \cdot R}{E}\right) + 0.675 - \frac{E}{R} \cdot \frac{1}{T}. \quad (11)$$

However, this model is restricted to a constant heating rate. In the applications of DAEM, it has been utilised to estimate the behaviour of different combinations of lignocellulosic biomass (pine wood) and polymer wastes (i.e., waste tyre, polylactic acid, PS, PET, PP, and HDPE) [34]. Besides that, this method has been incorporated into an ANN model to predict the pyrolytic properties of *Staghorn sumac* [106].

4.4 Optimisation methods

Optimisation methods or often referred to as heuristic models, such as genetic algorithm (GA), and particle swarm optimisation (PSO), shuffled complex evolution (SCE) are algorithms that could solve global optimization problems, i.e., for the pyrolysis process, the optimisation of the kinetic parameters to find the best fit using the data from the TGA. These optimisation methods generally solve problems by subjecting it to an objective function to determine the fitness of the iterations [109]. The objective functions or optimisation targets for a thermal degradation problem are the mass loss $\varnothing_{\mathrm{m}}$ and the mass loss rate $\varnothing_{\mathrm{mlr}}$ in Eqs. (12)–(14) as follows:

$$\varnothing = \varnothing_{\mathrm{m}} + \varnothing_{\mathrm{mlr}}, \quad (12)$$

$$\varnothing_{\mathrm{m}} = \sum_{j=1}^{N}\left[W_{CML,j}\frac{\sum_{k=1}^{n}(CML_{\mathrm{mod},k} - CML_{\mathrm{exp},k})^2}{\sum_{k=1}^{n}\left(CML_{\mathrm{exp},k} - \frac{1}{n}\sum_{p=1}^{n}CML_{\mathrm{exp},p}\right)^2}\right], \quad (13)$$

$$\varnothing_{\mathrm{mlr}} = \sum_{j=1}^{N}\left[W_{MLR,j}\frac{\sum_{k=1}^{n}(MLR_{\mathrm{mod},k} - MLR_{\mathrm{exp},k})^2}{\sum_{k=1}^{n}\left(MLR_{\mathrm{exp},k} - \frac{1}{n}\sum_{p=1}^{n}MLR_{\mathrm{exp},p}\right)^2}\right], \quad (14)$$

where CML_{mod} and CML_{exp} are the model and experimental cumulative mass loss, respectively; MLR_{mod} and MLR_{exp} are the model and experimental mass loss rate, respectively; N is the number of experiments, n is the number of data points for each experiment; and W_{CML} and W_{MLR} are the weighted value which can be defined as 1.

4.4.1 Genetic algorithm (GA)

The GA is based on an evolutionary concept to find the optimal solution to a complex problem globally. Firstly, the algorithm is initialised by carrying out a range search from a set of randomised candidate solutions referred to as a population. Each candidate solution is defined as an individual or a chromosome, containing the target parameters to be optimised (i.e., for the pyrolysis process, A, E_α and $\varnothing$), where the parameters are defined as genes in the GA [109]. Following the natural survival of the fittest, the population experience evolution forming subsequent generations according to the fitness of the objective function. Besides that, the new generation is produced by the chromosomes crossing over, exchanging information, and allowing mutation, this method helps to prevent the local optimal solution. Finally, by the process of elimination of relatively "unfit" candidate solution and reproducing generations that are "fit". The application of GA in thermal degradation experiments are quite common, it is applied to solve the hybrid pyrolysis scheme of combining both parallel and convective first order reaction. Besides that, recent studies have combined it with different algorithms to improve the performance of the model, according to Aghbashlo et al. [110], the study combines GA with Adaptive Neuro–Fuzzy Interference System (ANFIS) achieving predictions of the kinetic parameters with better fitting compared to traditional ANFIS model; GA-least squares fitting procedure [111], where GA is applied to generate the initial guess for the least square function to solve for the optimal solution. This reduces the number of iterations required for the least square.

4.4.2 Particle swarm optimization (PSO)

The PSO algorithm follows the velocity and position search model. It contains a certain number of particles, their positions, and velocity. The particles in a particular position represent a candidate of solution of space, and the velocity of this particle updates the position of these particles [112]. In addition, these particles have a memory ability which, retains its historical best position vector and its global best position found [109]. Initially, the particles are assigned a random position and velocity in a proposed range. The solution then improves with iterations via Eqs. (15) and (16):

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1 r_1\left(p_{id} - x_{id}^{k}\right) + c_2 r_2\left(p_{\mathrm{g}d} - x_{id}^{k}\right), \quad (15)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}, \quad (16)$$

where k is the iteration number, i is the particle number, and d is the search direction from 1 to D, w is the inertia weight, p_{id} and $p_{\mathrm{g}d}$ are the local particle position and the global best position of all particles, respectively. c_1 and c_2 are the two positive acceleration constants for the local and global nature of the swarm. r_1 and r_2 are the stochastic values in the range of [0,1], respectively [113,114].

According to Ding et al. [109], the study compares the performance between PSO and GA, and the results indicate that PSO showed closer global optimum convergence, 0.053 at the population size of 2500 compared to GA, with the best value at 0.075 at the population size of 2000. Besides that, PSO showed less

fluctuation, 0.05 to 0.08 in fitting values regardless of population size, compared to GA, which fluctuates between 0.07 and 0.29. In literature, PSO is often coupled with other algorithms, such as global sensitivity analysis, to find the parameters with the greatest effect on the prediction outcome. According to Ding et al. [112], the sensitivity order is ranked from the largest to the smallest value which are representing the activation energy of lignin, the reaction order of cellulose, and the pre-exponential factor for lignin in the pyrolysis process of pinewood. While for the co-pyrolysis of microalgae *Chlorella vulgaris* and HDPE, the activation energy of cellulose, pre-exponential factor for cellulose and the activation energy of protein, followed by the reaction order of cellulose, showed significant influence on the prediction results, indicating these parameters should be paid much attention for the pyrolysis process [115]. Besides that, Monte Carlo simulations were applied to perform uncertainty analysis, to probabilistically assess the effects of stochastic uncertainties in the predictor values (n = 100000) from the ANN and PSO framework [113]. In addition, a recent study proposed a neuro-evolution algorithm, progressive deep swarm evolution (PDSE), built on the PSO algorithm, to model the catalytic thermal degradation of *Chlorella vulgaris* [88]. From the validation tests, implementing the PDSE algorithm obtained a coefficient of determination (R^2) value above 0.9990, RMSE below 0.0075, and MBE below 0.0026.

4.4.3 Shuffled complex evolution (SCE)

The SCE algorithm introduced by Duan et al. [116] is effective for calibration of hydrological models. The efficacy of this algorithm, a form of differential evolution (DE), comes from its use of geometric operations to find possible optimal solutions to space parameters. The algorithm solves global optimisation problems based on four concepts: (1) probabilistic and deterministic approaches; (2) clustering; (3) systematic evolution of a complex of points spanning the space in the direction of global improvement and (4) competitive evolution. The application of SCE on the woody pyrolysis was studied with six different kinetic models, comprising of single component reactant mechanism, and multicomponent reactant mechanisms (i.e., cellulose, hemicellulose, and lignin) [117]. The optimised kinetic parameters from the results were applied to predict the pyrolysis process with different heating rates, 5 and 80 °C·min^{-1}), where the results were found better fitting of the results of the multicomponent kinetic model, which can reach R^2 values of up to 0.99 [117]. Besides that, SCE has been applied in various pyrolysis kinetic analysis, pyrolysis of beech [118], and pyrolysis of basswood waste [119].

The SCE algorithm starts with generating of a population of random points within the search space, denoted as s. Each of these points contains a vector (i.e., kinetic parameters) and is ranked based on their fitness function value and stored in an array D, and partitioned into p complexes, each containing m points, i.e., $D = \{A^k, k = 1, ..., p\}$. Next, each complex evolved using the competitive complex evolution algorithm, and shuffled. All points are combined to a single population and the procedure of ranking for the function value, partition into complexes, evolution, and shuffling is repeated until convergence value is reached [116,120].

4.5 Predictive models: artificial neural network (ANN)

ANN is an intelligent learning, predictive computational technique, often employed to solve the nonlinear, and complex relationships between the input and output data. An ANN network consists of one or more hidden layers connecting the input (i) and output (o) layers. Each layer has a weight (w) matrix and an output vector [121]. The neuron of each single layer picks up the summation of the activation from the input vectors and their assigned weights and biases, the results then pass through an activation function (i.e., linear, sigmoid, and hyperbolic tangent sigmoid) to generate a new activation value to the neurons in the following layers. The weight matrix is altered to fit the learning algorithms, the learning ends when the weights of each layer achieve convergence as the final output vector (y_o) [122,123]. The ANN parameters influencing the performance are: the number of hidden layers (j), the number of neurons in each hidden layer (n), and the transfer function deployed denoted as f. The general architecture of the ANN is illustrated in Fig. 4.

Generally, the model learning process involves inputting a percentage of sample data to the network, and altering the number of neurons in the hidden layers to optimise the mean square error (MSE) [51]. Besides that, the selection is supervised by a learning algorithm. In literature, this method has been applied in predicting of the kinetic parameters of the pyrolysis process, involving the iso-conversional models, i.e., KAS and FWO shown in Table 7.

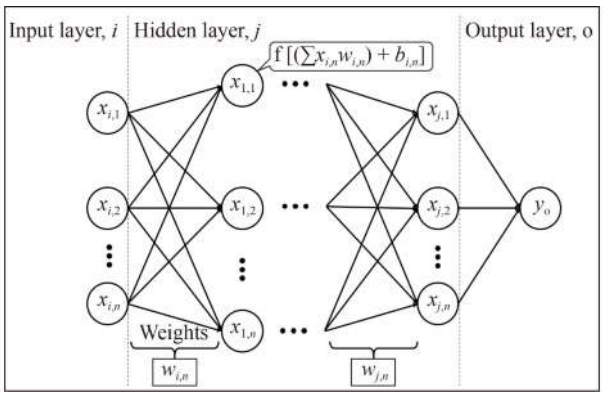

Fig. 4 General ANN architecture.

4.6 Thermodynamics relations

The thermodynamic parameters are important for the scale up and the design of the reactor, i.e., Frequency factor, A (s^{-1}), change in enthalpy, ΔH ($kJ \cdot mol^{-1}$), Gibbs free energy, ΔG ($kJ \cdot mol^{-1}$), and change in entropy, ΔS ($kJ \cdot mol^{-1} \cdot K^{-1}$). The parameters are expressed in the respective equations as Eqs. (17)–(20):

$$A = \frac{\beta \cdot E \cdot \exp\left(\frac{E}{R \cdot T_m}\right)}{R \cdot T_m^2}, \tag{17}$$

$$\Delta H = E_\alpha - R \cdot T, \tag{18}$$

$$\Delta G = E_\alpha + R \cdot T_m \cdot \ln\left(\frac{K_B \cdot T_m}{h \cdot A}\right), \tag{19}$$

$$\Delta S = \frac{\Delta H - \Delta G}{T_m}, \tag{20}$$

where T_m, K_B, h are the maximum temperature where the decomposition occurs (K), Boltzmann constant (1.381×10^{-23} $J \cdot K^{-1}$), and Plank's constant (6.626×10^{-34} $J \cdot s$) [30]. $A < 10^9$ s^{-1} refers to a simpler straightforward reaction, while $A > 10^9$ s^{-1} would mean the reaction follows a complex mechanism [129]. ΔH represents the endothermic or exothermic behaviour of the reaction mechanism; it is the amount of energy transferred during a chemical reaction. According to Gan et al. [130], the smaller the difference of ΔH with the E_α is, the more favourable for the reaction to occur. Hence, the bioenergy from the system is more likely to be attained. Moreover, ΔG is the total potential energy increased in the system, it signifies that the reactants are consumed and activated complexes are formed [21]. The ΔG also represents the suitability of the feedstock for pyrolysis, the higher the ΔG is, the more bioenergy can potentially be attained [30,51]. Furthermore, ΔS is the degree of arrangement of the carbon in the waste and biomass. It is the amount of energy unavailable to work. For higher entropy values, it indicates that the sample has yet to achieve thermodynamic equilibrium, and is highly reactive [131]. Table 8 summarises the kinetic and thermodynamic parameters for different feedstock samples.

5 Future outlooks

Many studies have proven that the combination of feedstock, biomass with waste plastic or biomass with waste tire in co-pyrolysis, with enhancements in the pyrolysis oil through synergistic effects, is an economical way for the production of sustainable fuel as a replacement for fossil fuels. The combination of waste plastics (20 wt %) with biomass generated a higher pyrolytic liquid yield compared to the solely thermal pyrolysis of biomass. This phenomenon shows that the oil produced from co-pyrolysis process can be blended with diesel after minor upgrading or even directly applied in transportation [132]. Nonetheless, not all plastic types can be applied in the process. In this sense, PVC, which consists of about 57% chlorine by weight, is not an ideal feedstock material as it will thermally break down into a very corrosive and toxic hydrochloric acid and influence the diesel quality with the production of chlorinated hydrocarbons. A 0.0145–0.0290 $mg \cdot m^{-3}$ of total chloride level has been recorded in the fuel oil product with just merely adding 1%–3% PVC in the feedstock stream [133,134]. Besides that, Hu et al. [32] stated that more studies are needed for co-pyrolysis especially in establishing a suitable approach in selecting material and the optimum blending ratio of material with biomass [32].

Furthermore, constraints in having straightforward and efficacious characterisation strategies for co-pyrolytic oil also impede the dependence of the industrial community in the technology [135]. Despite the extensive research works on the invention of the co-pyrolysis approach using

Table 7 ANN model compilation from different studies

Biomass/catalyst	Learning algorithm/ topology	Prediction result	ANN parameters	Ref.
Chlorella vulgaris limestone, HZSM-5	PDSE	Thermal degradation	Inputs: heating rate; heat flow; reactor temperature Outputs: remaining mass	[88]
Rice husk, sewage sludge	Levenberg–Marquardt (LM)	Thermal degradation	Inputs: reactor temperature; blend composition Outputs: mass loss	[21]
Chlorella vulgaris, peanut shell, microalgae ash	LM	Thermal degradation	Inputs: heating rate; reactor temperature Outputs: mass loss	[124]
Sewage sludge, peanut shell	LM	Thermal degradation	Inputs: blend compositions; heating rates; reactor temperature Outputs: remaining mass	[122]
Rice husk	Scaled conjugate gradient and LM	Thermal degradation	Inputs: heating rate; reactor temperature Outputs: remaining mass	[125]
Lignocellulosic biomass	Random forest schematic	Biochar yield	Dataset: physicochemical properties of lignocellulosic biomass	[126]
Sewage sludge	LM	HHV of syngas	Dataset: physicochemical properties of biomass	[127]
Mexican sunflower (*Tithonia diversifolia*)	LM	Bio-oil yield	Inputs: heating rate; flow rate; particle size; reactor temperature Output: bio-oil yield	[128]

Table 8 Kinetic and thermodynamic parameters of the pyrolysis process in literature

Feedstock	Catalyst	Kinetic model	E_α/ (kJ·mol^{-1})	A/ min^{-1}	ΔH/ (kJ·mol^{-1})	ΔS/ (J·mol^{-1}·K^{-1})	ΔG/ (kJ·mol^{-1})	Ref.
Pterocarpus indicus	–	Coats-redfern	112.0	–	103.0	–138.0	183.00	[35]
Intsia bijuga	–		99.0	–	89.0	–120.0	160.00	
Corn stover	–		66.0	–	57.0	–173.0	147.00	
HDPE	–		546.0	–	533.0	420.0	226.00	
LDPE	–		487.0	–	475.0	348.0	231.00	
PP	–		423.0	–	411.0	273.0	222.00	
Rice hull	–	DAEM	175.4	2.939×10^{17}	170.2	–	–	[130]
	–	FWO	177.7	7.991×10^{16}	172.6	–	–	
	Limestone	DAEM	123.3	5.803×10^{11}	117.9	–	–	
	Limestone	FWO	132.5	4.148×10^{12}	127.1	–	–	
	Eggshell	DAEM	96.1	2.033×10^{10}	90.8	–	–	
	Eggshell	FWO	100.4	1.948×10^{9}	95.2	–	–	
Sewage sludge (97.5% conversion)	–	KAS	123.6	1.440×10^{6}	119.5	139.4	187.69	[51]
	–	FWO	132.7	1.560×10^{9}	128.6	138.8	196.50	
	–	Friedman	92.4	0.0103	88.3	295.4	232.80	
	–	Popescu	200.9	9.740×10^{10}	196.8	219.3	304..00	
Microalgae:microalgae ash:peanut shell 9:2:9	–	FWO	142.6	2.010×10^{14}	137.0	–	–	[124]
Garlic husk	–	KAS	154.0	–	149.4	–	150.60	[104]
	–	FWO	154.9	–	150.4	–	150.50	
	–	Starink	154.3	–	149.8	–	150.50	
Staghorn sumac	–	FWO	167.9	–	178.9	–	–	[106]
	–	KAS	169.4	–	167.2	–	–	
	–	Starink	169.8	–	167.6	–	–	
Azadirachta indica	–	FWO	–	6.288×10^{15}	188.5	–43.3	215.40	[30]
	–	Friedman	–	8.586×10^{15}	190.9	–39.4	215.40	
	–	Vyazovkin	–	2.965×10^{20}	199.7	–26.0	215.20	
Phyllantus emblica	–	FWO	–	2.075×10^{14}	189.9	–40.9	215.30	[30]
	–	Friedman	–	2.864×10^{13}	181.3	–55.1	215.60	
	–	Vyazovkin	–	3.534×10^{13}	179.4	–58.3	215.60	
Rice husk	–	Friedman	–	–	186	–	–	[92]
	–	KAS	–	–	178	–	–	
	–	FWO	–	–	180	–	–	
	Rice hull ash	Friedman	–		148	–	–	
	Rice hull ash	KAS	–	–	148	–	–	
	Rice hull ash	FWO	–	–	146	–	–	
Chlorella vulgaris	–	KAS	156.2	2.898×10^{20}	151	–	–	[131]
	–	FWO	158.1	2.358×10^{20}	153	–	–	
	HZSM-5	KAS	145.3	2.790×10^{14}	140	–	–	
	HZSM-5	FWO	147.8	4.908×10^{14}	143	–	–	
	Limestone	KAS	138.8	6.360×10^{15}	133	–	–	
	Limestone	FWO	142.1	8.880×10^{15}	137	–	–	

different kinds of agricultural biomass and polymer wastes, the current heat transfer processes for co-pyrolysis, i.e., conduction, convection and radiation still impose several challenges. In conduction, solid attrition is the critical issue once there is a direct contact between fuel particles and heating agent. In convection, small fuel particles and long gas residence times are essential for gas/solid and sufficient heat transfer, respectively. Asymmetrically, the primary challenges of radiation are high concentration of radiation is required for the production of sufficient heat transfer and consideration of wall heating design in pyrolysis reactor [136,137]. Hence, the high installation and operating costs of units with a high efficiency of heat transfer in the short gas residence time and an additional pre-treatment system for various types of biomasses are the main drawbacks of co-pyrolysis. Different studies reported that different conditions are required to blend an appropriate waste with different biomasses before co-processing. More profound fundamental studies on reaction mechanisms and kinetics of biomass with different waste materials are critical in the advancement of the co-pyrolysis process. In this sense, the properties of the co-pyrolytic oil produced with its composition can be determined from the interactivity

of the reaction intermediates. Currently, ANN and Monte Carlo serve as empirical models that are practical in the prediction of intricate input–output interrelations in a co-pyrolysis process. However, these models are only applicable to the process and fuels, which have been well-established [21]. Co-pyrolysis kinetic datasets for predicting of product formation using different reactor systems are still fairly unexplored [135].

Moreover, the commercialisation of co-pyrolysis reactors are still in the early stages since the current reactors still have the challenges of low heat efficiency, high capital and operating costs as well as complexities with biomass handling or storage [32]. Besides that, although there is plenty of extensive research on the single feedstock pyrolysis, the feasibility study of the co-pyrolysis process remains a niche area, whereby research on the techno-economic and life cycle assessment of the process is limited to single feedstock pyrolysis, such as the co-pyrolysis of biomass refineries and the DFM layers in these references [138,139]. To the best of our knowledge, these studies for the case of co-pyrolysis are scarce, existing studies focus on the microwave co-pyrolysis of food waste and LDPE [140], and the co-pyrolysis of lignite coal with single-use plastic waste [141]. Besides that, the existing research on the modelling of the co-pyrolysis of biomass with plastic waste reaction kinetics has been widely studied, but yet to have a consensus on the reaction pathway [32].

6 Conclusions

To conclude, the recent technologies and techniques of co-pyrolysis of biomass and plastic waste to produce bio-oil have been summarised in this review. The growing agriculture industry in ASEAN countries to suit the growing population of the region, has subsequently generated landfills of biomass. To exacerbate the situation, the global pandemic gives rise to the surge of the single-use plastic waste, DMFM wastes. Fortunately, the exploitation of these wastes in co-pyrolysis would positively improve the quantity and quality of the extracted bio-oil of the process, as the result of the synergistic interactions between lignocellulosic properties of biomass and the high hydrogen content of the plastic wastes. Furthermore, the advancement of the kinetic analysis of the pyrolysis process has improved as the catalytic co-pyrolysis process becomes more complex, and unable to be explained via simple iso-conversional models. Advanced conversional models such as Vyazovkin and DAEM methods have been introduced to study the pyrolysis reaction, followed by the heuristic model and predictive models, which prove to produce high-accuracy results. However, the studies of co-pyrolysis of biomass and DMFMs remain limited. Experimental work on the binary feedstock's thermal decompositions and the bio-oil product's quantity and quality result from the co-pyrolysis has yet to be clear. The proposal of this methodology could serve as potential solution to help reduce or eliminate the pollution caused by the DMFM wastes, while producing value-added bio-oil products.

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REVIEW ARTICLE

A review on co-pyrolysis of agriculture biomass and disposable medical face mask waste for green fuel production: recent advances and thermo-kinetic models

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Abstract The Association of Southeast Asian Nations is blessed with agricultural resources, and with the growing population, it will continue to prosper, which follows the abundance of agricultural biomass. Lignocellulosic biomass attracted researchers' interest in extracting bio-oil from these wastes. However, the resulting bio-oil has low heating values and undesirable physical properties. Hence, co-pyrolysis with plastic or polymer wastes is adopted to improve the yield and quality of the bio-oil. Furthermore, with the spread of the novel coronavirus, the surge of single-use plastic waste such as disposable medical face mask, can potentially set back the previous plastic waste reduction measures. Therefore, studies of existing technologies and techniques are referred in exploring the potential of disposable medical face mask waste as a candidate for co-pyrolysis with biomass. Process parameters, utilisation of catalysts and technologies are key factors in improving and optimising the process to achieve commercial standard of liquid fuel. Catalytic co-pyrolysis involves a series of complex mechanisms, which cannot be explained using simple iso-conversional models. Hence, advanced conversional models are introduced, followed by the evolutionary models and predictive models, which can solve the non-linear catalytic co-pyrolysis reaction kinetics. The outlook and challenges for the topic are discussed in detail.

Keywords biomass, COVID-19 waste, catalyst, pyrolysis, kinetics

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1 Background

1.1 Bioenergy from biomass as a crucial renewable energy source

Association of Southeast Asian Nation (ASEAN) projected its population to grow by 100 million from 2014 to 2025, with an annual growth of 5%, and 4% in energy demand per year. Hence, the association has set the goal to increase its renewable energy share from 9.4% to 23% of the primary energy supply in the ASEAN region [1]. In order to meet the target, member countries has strategise several policies, laws, and regulations [2], as summarised in Table 1, which includes ASEAN member countries and their strategies [3].

Following this, ASEAN countries are known as the top agriculture producers. Hence, there are significant prospects for bioenergy as a strategy to help realise the ASEAN renewable energy generation and consumption goals. For example, Indonesia and Malaysia are the major players in the oil palm industry, followed by Thailand as

Table 1 ASEAN member countries renewable energy policies

Country	Policies/strategies	Ref.
Cambodia	**Energy Sector Development Policy and Rural Electrification Policy, 2007** Rural electrification fund subsidy and investment incentives are provided as support to the policy • Providing reliable, affordable quality supply of electricity to the consumers • Promoting private-owned facilities in the renewable energy sector to instigate competition between the companies • Providing electricity to 70% of the rural households by the year 2030	[4]
India	**The Electricity Act, 2003** • To encourage the co-generation of electricity with renewable sources • Specify the terms and conditions for the determination of tariff, which forms the National Electricity Policy and the Tariff policy **Tariff Policy, 2006** • States that renewable energy shall be distributed with a preferential tariff determined by the appropriate commission • Bidding process within suppliers offering renewable energy from the same source **National Rural Electrification Policies, 2006** • Provision of access of electricity to all households by the year 2009 • Quality and reliable power supply at affordable rates • Providing off grid solutions for rural areas **Integrated Energy Policy Report (Planning Commission), 2006** Recommends a solution to meet the energy demand of India in an integrated process up to 2031–2032	[5]
Indonesia	**Government Rule No. 3 on Supply of Electricity, 2005** To ease the private-own power producers to set up renewable energy plants **Blueprint of National Energy Implementation Program 2005–2025** • To outline plans for energy supply security • To provide guidelines for various sectors involving renewable and non-renewable energies • To provide subsidies to enhance energy efficiency **Presidential Regulation No. 5 on National Energy Policy, 2006** • To set goals to promote diversification of energy sources • To reduce energy consumption by 1% per year as target **Presidential Decree No. 1 on Supply and Use of Biofuels, 2006** Setting targets and guidelines for biofuels utilisation and development **Ministerial Regulation No. 2 on Medium Scale Power Generation from Renewable Energy Sources, 2006** To set pricing guidelines for projects ranging from 1 to 10 MW **Energy Law, 2007** Providing renewable energy developers with investment incentives **Electricity Law, 2010** To encourage private companies to participate in energy supply To provide priority in the utilisation of renewable energy To promote small scaled distributed power generation from renewable sources **Ministerial Regulation No. 4/2012, 2012** To set the Feed-in-Tariff for electricity generated from biomass **Ministerial Regulation No. 27/2014, 2014** • To set goals to increase the renewable energy portion to 23% by the year 2025, and 31% by 2050 • Feed-in-tariffs for renewable energy • To encourage the government and private sectors to utilise biofuels for power generation	[6]
Malaysia	**Five-Fuel Diversification Policy, 2001** To include renewable energy in the energy supply mix of power generation **National Biofuel Policy, 2006** • To reduce dependency on fossil fuels • Providing subsidies to promote the demand for alternate sources of energy **National Renewable Energy Policy and Action Plan, 2010** • Increase the renewable energy contribution in the energy supply mix • Promote growth of the renewable energy sector • Maintaining the renewable energy at an affordable price • Instigate awareness to the community on renewable energy	[7]
Thailand	**Committee on Biofuel Development and Promotion (CBDP), 2008** Government subsidies from the State Oil Fund biodiesel price reduction **Second Alternative Energy Development Plan (2008–2022), 2008** • To increase the proportion of alternative energy to 20% of the national total energy consumption by 2022 • To utilise renewable energy as a substitute for imported oil • To increase energy security of Thailand • Promote integrated green energy utilisation in communities • Enhance the development of alternative energy industry • Research and development of efficient technology to harvest renewable energy	[8]
Vietnam	**Renewable Energy Action Plan, 2001** Government intervention to promote renewable energy **The Law of Electric, 2004** Support electricity generation from renewable sources by providing investment incentives, preferential electricity prices and taxes **Decision 1855/QD-TTg: 27 Dec 2007** • National Energy Development Strategy up to 2020 with outlook to 2050 • To encourage the development of new and renewable energies, bioenergy to meet the socioeconomic requirements • To meet the target of 5% of primary commercial energy by 2020 and 11% by 2050 **Decision No. 177/QD-TTg:20 Nov 2007** • To develop biofuel, as an alternative for fossil fuels • To build a legal framework for biofuel development • To develop materials for biofuel production • To enhance biofuel extraction **National Program for Biofuels Development, 2011** • Develop biofuel to partly replace fossil fuels • Create the legal framework for biofuel development • Develop relevant materials for biofuel production • Develop biofuel extraction technologies	[9]

(*Continued*)

Country	Policies/strategies	Ref.
Myanmar	**Myanmar Energy Master Plan, 2015** • To study the energy demand development from 2014 to 2035 • To set a goal to achieve 15%–20% share of renewable energy in 2020 • To improve the rural renewable energy usage • To achieve 57% hydropower, 5% solar and wind by 2030	[10]
Laos	**The Electric Law, 1997** Setting standards for the administration, production, distribution, transmission and the import and export of electricity **The Power Sector Policy Statement, 2001** • To increase the electricity supply rate to 90% by 2020 • Promotes the public and private partnerships in hydropower development (500 kV grid) **The 8th National Socio-economic Development Plan (NSEDP), 2016–2020** Promotes sustainability and diversification of renewable energy sources **The Renewable Energy Development Strategy** To increase the renewable energy share to 30% and substitute 10% of the transport fuel with biofuels by 2025	[11]
Philippines	**R. A. No. 9367: The Biofuels Act, 2006** Encourage the utilisation of biofuel-blended transport fuels by providing fiscal incentives **R. A. No. 9513: The Renewable Energy Act, 2008** • Enhance the renewable energy development by providing fiscal and non-fiscal incentives • To reduce the country's reliance of fossil fuels • Adopts renewable portfolio standards, feed-in-tariffs, net-metering, and Green Energy Option policy instruments	[12]

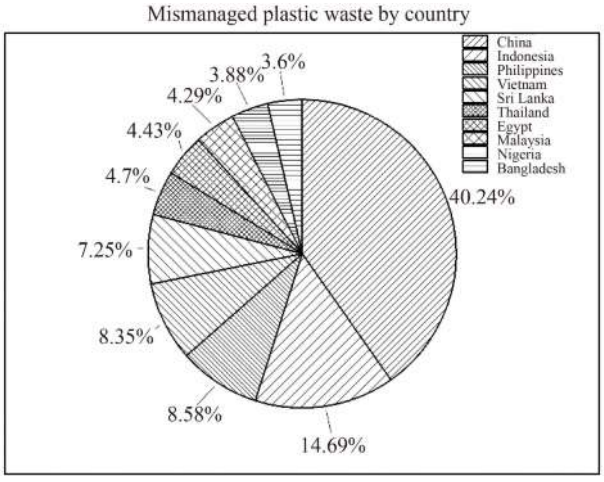

Fig. 1 Mismanaged plastic waste generated by countries. Reprinted with permission from Ref. [24], copyright 2015, American Association for the Advancement of Science.

shown in Fig. 1. In Indonesia, the production volume reached 45.86 million tonnes in 2019 [13]. Meanwhile, Malaysia produced 18.5 million tonnes in the same year [14]. However, the palm oil produced only represents 10% by weight of the total harvest; and the remainder contributed to the oil palm biomass, i.e., oil palm empty fruit bunch (EFB), palm kernel shell (PKS), palm pressed fibres (PPF), and oil palm frond [15]. To accommodate the rising population, food demand such as rice and wheat production in India has grown dramatically. In 1960, rice and wheat production was 34.6 and 11 million tonnes, respectively, and had risen to 118.9 and 107.6 million tonnes respectively in 2019 [16]. The rapid generation of biomass poses sustainability issues and waste management complications. Fortunately, this agriculture biomass is made up of lignocellulosic constituents, which include cellulose (23.3–44.9 wt %), hemicellulose (17.3–34.0 wt %), and lignin (12–53.5 wt %) [17]. Cellulose is a complex polymer of glucose held by β-1,4-glycosidic bonds, intramolecular and intermolecular H-bonds. Hemicellulose is a heterogeneous polysaccharide, consisting of hexoses (i.e., glucose, mannose, galactose, xylose, arabinopyranose, arabinofuranose, and glucuronic acid). Lignin is made up of guaiacyl propane, syringyl propane and *p*-hydrophenyl propane [17,18]. These constituents serve as the basic precursors for the conversion into fuel, fibres, and aromatics [19]. Other properties from the proximate and ultimate analysis are depicted in Table 2, which shows that the biomass contains 50 to 70 wt % of volatile matter. In comparison, the carbon and hydrogen contents are 36–53 and 5.0–7.3 wt %, respectively.

Besides that, plastic or polymer waste generation has increased over the years. According to Geyer et al. [23], the study reports that cumulative plastic waste generation of primary and secondary plastic has reached 6300 million tonnes from 1980 to 2015. Only 12% of these plastic wastes were incinerated, while 9% were recycled. Furthermore, according to Jambeck et al. [24], ASEAN member countries such as Indonesia, Philippines, Vietnam, Thailand, and Malaysia contributed approximately 41% of the mismanaged plastic waste as illustrated in Fig. 1. Moreover, according to Abnisa and Alaba [25], the global composition of plastic wastes comprises of 26.67% low density polyethylene (LDPE), 25.33% polypropylene (PP), 18.67% high density polyethylene (HDPE), 14.67% polyethylene terephthalate (PET), 8% polystyrene (PS), and 6.67% polyvinyl chloride (PVC). Furthermore, with the rapid rise of confirmed cases of the novel coronavirus disease (COVID-19), the need for personal protective equipment (PPE) is high, resulting in the rapid generation of COVID-19 related wastes, exacerbating the current plastic waste management issue. According to Liang et al. [26], there are two categories of COVID-19 related wastes which are (1) wastes generated

Table 2 Proximate and ultimate analysis of different agriculture biomasses [20–22]

Sample	PKS	PPF	EFB	Rice husk	Rice straw (RS)	Bagasse
Proximate analysis/(wt %)						
Moisture	5.73	6.56	8.75	4.50	–	–
Ash	2.21	5.33	3.02	12.40	13.60	6.50
Volatile matter	73.74	75.99	79.67	58.60	70.10	72.70
Fixed carbon	18.37	12.39	8.65	24.40	16.30	20.80
Ultimate analysis/(wt %)						
C	53.78	50.27	48.79	43.20	37.10	36.30
H	7.20	7.07	7.33	5.00	5.20	5.80
S	0.51	0.63	0.68	0.00	0.10	0.00
N	0.00	0.42	0.00	0.30	0.50	0.30
O	36.3	36.28	40.18	51.4	43.5	51.10

from within hospitals or healthcare facilities, which are considered medical wastes and are collected and disposed of with appropriate measures (i.e., identification, collection, separation, storage, transportation, treatment, and disposal) [26], and (2) the wastes generated outside those facilities, which include disposable medical face masks (DMFM) and gloves. These wastes do not have proper waste management and are often treated as municipal solid, and plastics wastes. Besides that, according to the World Health Organisation (WHO) [27], the demand for these PPE, i.e., DMFM, and gloves, is expected to rise 20% by the year 2025. If these wastes are not managed properly, it will lead to major environmental complications. In some parts of the ASEAN region (i.e., Cambodia, Philippines, India, and Indonesia), poor waste management issues such as landfills and illegal dumping were present even before COVID-19. These uncontrollable landfills would escalate into space limitations and release toxic pollutants to the environment [28]. Moreover, the random disposal of these wastes could also lead to microplastic pollution, accumulating in the food chain, especially in aquatic life [29].

1.2 Biomass and polymer waste conversion pathways: pyrolysis

Therefore, strategies to recover energy from these wastes are keys to minimize the waste accumulation and their impacts to the environment. To convert these high-energy feedstocks into valuable fuel, there are two main pathways to convert the lignocellulosic biomass and plastic wastes into biofuels or green fuels, i.e., bio-chemical conversion and thermochemical conversion. In bio-chemical conversion, the larger and complex compounds are broken down into simpler molecules, with bacteria and enzymes. However, this method has limited feedstock options, and is not suitable to convert synthetic polymers like plastic wastes [30]. Besides that, thermochemical conversion includes low-temperature carbonisation, intermediate-temperature pyrolysis, and high-temperature gasification. Among these thermochemical processes, pyrolysis represents a promising technology in terms of high fuel-to-feed ratios [31]. In addition, the pyrolysis process is favoured as the process that can be carried out at atmospheric pressure and faster conversion rates (<1 s) [32]. Moreover, the pyrolysis process is compatible with a wide variety of feedstocks aside from lignocellulosic biomass, i.e., plastics, and waste tires [33–36]. The pyrolysis process involves-production of biofuel in the form of bio-oil, as well as producing valuable bio-chemicals such as alcohols, aldehydes, ketones, acids, furans, anhydrosugars, and phenols from biomass [37]. Fast pyrolysis yields the highest amount of bio-oil (65–75 wt %), while slow pyrolysis produces less bio-oil (20–50 wt %), with a larger proportion of bio-gas (20–50 wt %) and biochar (25–35 wt %) [38]. A detailed information on the different pyrolysis modes can be found in these references [38–43].

This paper focuses on the issues of the growing generation of biomass in ASEAN region, as well as the single-use plastics (i.e., DMFM) generated due to the COVID-19 pandemic. Following this, this review outlines the potential of co-pyrolysis of the biomass with plastic wastes as a technique to produce value-added bio-oil. Besides that, this review also looks into the technologies, (i.e., catalyst selection) and technical aspects (i.e., pyrolysis parameters) of the co-pyrolysis process. In addition, the kinetic models, and the advancements to describe the catalytic co-pyrolysis of biomass and plastic wastes are also outlined. Finally, the outlook detailing the significance and the limitations of the co-pyrolysis technique is discussed.

2 Bibliometric analysis

Bibliometric analysis is defined as the analysis of scientific publications using statistical methods to provide an outline of the research area [44]. Several publications have adopted this method in research areas of bio-diesels [45], municipal solid waste management [44], invest-

ments [46], and even COVID-19 [47]. This method of analysis provides a systematic way to sort and analyse a great number of publications, in terms of citations, co-citations, author keywords, and countries.

In this project, the bibliometric analysis of the field of pyrolysis of biomass was conducted in VOSviewer1.6.11. The utilisation of the software has been widely employed in this study, providing a visualisation of the relationships between publications in a research area or topic. The online publication database platform, Scopus, was utilised in the collection of the database for this study. The search phrase and Boolean Operators for this study were "pyrolysis AND biomass AND plastic AND bio-oil OR oil palm OR catalyst", the publication year was limited from 2019 to 2023, and limited to journal articles only. A total of 1448 publications were fitted into VOSviewer to analyse the co-occurrence of author keywords more than 20 times and are visualised in Fig. 2. The top-ranked link strength keywords, excluding the search phrases, include catalytic pyrolysis, co-pyrolysis, biochar, oxygen reduction reaction, and hydrogen. Based on this study, the current research trend involves around catalytic pyrolysis or co-pyrolysis, and focuses on the oxygen reduction, hydrogen and biochar formation from the process. Furthermore, another analysis of the bibliographic coupling of countries was carried out and the results were visualised in Fig. 3. The result suggests that China, United States, South Korea, Malaysia, and Australia are the active countries involved in this research area.

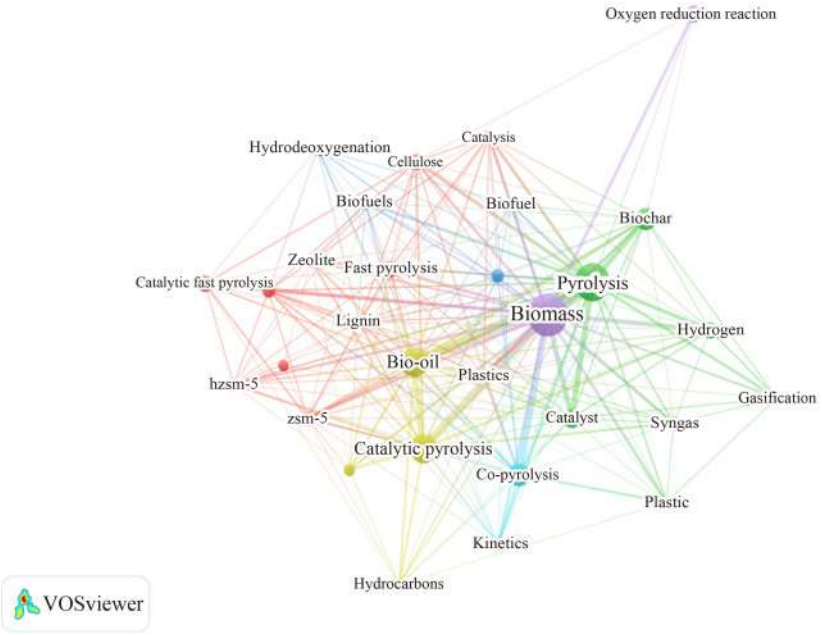

Fig. 2 Co-occurrence of author's keywords > 20 times by publication year.

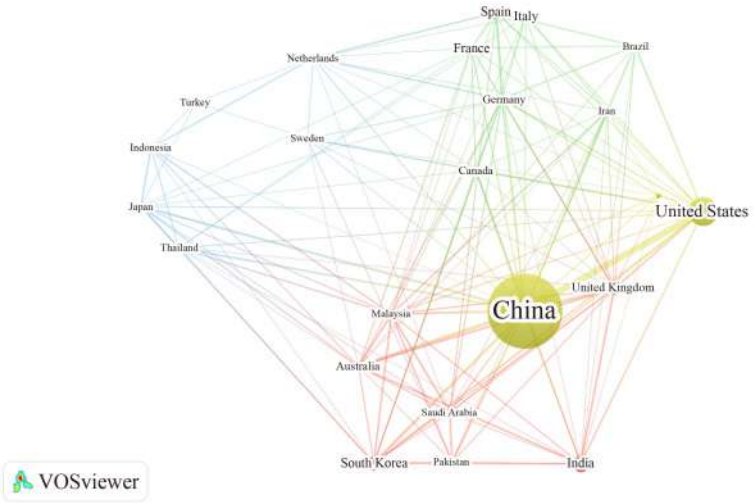

Fig. 3 Bibliographic coupling of countries by year.

3 Pyrolysis technologies/techniques for bio-oil production

Initially, most of the research studies focus on mono-component such as biomass [20,48–54] or plastic waste [55–60] in the pyrolysis process for bio-oil production. However, the pyrolysis of lignocellulosic biomass produces low quality bio-oil and yield [61]. Biomass-derived pyrolysis oil is high in oxygen content, corrosive in nature, and thermally unstable. Bio-oil generally requires upgradation using a hydrogen source and a catalyst, which makes the process complicated and expensive [37]. For plastic pyrolysis, the volatile products contain harmful compounds, i.e., polycyclic aromatic hydrocarbons (PAHs) [62–64]. PAH is a macromolecular aromatic compound with carcinogenic and mutagenic characteristics that pose health concerns upon exposure [65]. Hence, there is a growing interest in improving the pyrolysis process to produce bio-oil with enhanced properties, i.e., co-pyrolysis of two or more feedstock, and the utilisation of catalysts for product upgrading.

3.1 Mechanisms of co-pyrolysis with polymers

Hence, it is crucial to understand the reaction mechanism of co-pyrolysis of biomass and plastic wastes. Several studies have explored the co-pyrolysis of biomass with polymer wastes, i.e., RS and sugarcane bagasse with PP, and PS [34]; corn stover, ipil, and narra, with HDPE, LDPE and PP [35]; RS with waste tires [36]; sawdust with LDPE [66]. These studies show that the co-pyrolysis technique is promising in improving the bio-oil quality and calorific value, reducing energy costs by lowering the activation energy. According to Lin et al. [67], the widely accepted mechanism of co-pyrolysis of biomass with plastics can be summarised in a two-step mechanism: (1) the free radicals generated from the pyrolysis of biomass initiate the β-scission of the polymers, inhibiting the intermolecular and intramolecular H transfer, producing aliphatic hydrocarbons and reduced alkadienes; (2) the H transfers from the polymers reacting with the biomass-derived radicals to form stable compounds. This mechanism allows an increase in the decomposition rate of the biomass, greatly reducing the char yield as reported by Önal et al. [68]. The addition of a hydrogen-rich plastic waste to biomass influenced the energy recovery efficiency of bio-oil by affecting the real-time power output, reaction time, and changes in the bio-oil composition [69]. Besides that, the biomass decomposes first at a lower temperature forming free radicals, i.e., OH radicals. These radicals react with the pyrolysis products of plastic, larger molecular weight organics (C_{12}) were formed with the co-pyrolysis of biomass and LDPE [70]. According to Navarro et al. [34], this mechanism reduces the selectivity for the secondary reaction to occur, reducing the char yield (i.e., 8.6 and 10 wt % reduction of char with the co-pyrolysis of B and PS, B and PP, respectively). Besides that, according to a study by Ojha et al. [71], the formation of C_8–C_{20} alcohols was observed, which was explained by the reaction of hydrocarbon free radicals from PP, with water from the dehydration reaction from cellulose. According to Uzoejinwa et al. [72], synthetic polymers are derived from petroleum products with high carbon and hydrogen contents, low oxygen content, and contains high calorific values. Hence, making it suitable potential as a co-feedstock for the biomass pyrolysis. Furthermore, these polymer wastes also showed similar properties of high volatile matter, higher heating value (HHV) and lower heating value (LHV) than biomass, as observed in Table 3.

3.2 Pyrolysis reaction parameters that influence the bio-oil yield

During pyrolysis, multiple factors affect the outcome of the process, which are, reactor temperature, heating rate, feedstock particle size, and residence time. Studies on these parameters are crucial to improve the pyrolysis process in terms of bio-oil product yield and quality. Generally, the operating parameters are adjusted, to impede the secondary tar cracking reactions, which reduces the bio-oil yield.

3.2.1 Pyrolysis temperature

The role of temperature is to provide sufficient thermal energy for the decomposition of the biomass. It is important to note that for the main constituents of biomass, cellulose, hemicellulose, and lignin, their temperature degradation ranges are 225–325, 325–375, and 250–500 °C, respectively. Hence, an optimal temperature of 500 °C is sufficient to encompass these temperature ranges. Nevertheless, the optimal temperature differs with the compositions of varying feedstock [74]. Furthermore, according to Dai et al. [75], bio-oil yield peaks at the

Table 3 Proximate and ultimate analysis of polymers [22,34,60,73]

Sample	PP	PS	LDPE	HDPE	Waste tires
Proximate analysis/(wt %)					
Moisture	0.20	–	–	0.00	1.10
Ash	0.10	0.00	–	0.00	8.10
Volatile matter	99.80	99.50	99.98	100.00	62.50
Fixed carbon	0.00	0.50	0.02	0.00	28.20
Ultimate analysis/(wt %)					
C	85.40	89.50	85.47	85.34	84.60
H	14.50	8.50	14.21	12.22	7.70
S	0.00	0.00	0.11	0.00	1.40
N	0.00	0.00	0.08	0.00	0.40
O	0.00	2.00	0.13	2.44	4.30
HHV/(MJ·kg^{-1})	46.00	40.10	–	46.40	36.80
LHV/(MJ·kg^{-1})	43.10	–	–	43.10	35.10

temperature range of 450–550 °C; a further increase of temperature (> 600 °C), the bio-oil yield reduces, corresponding to an increase in non-condensable gas, or biogas. Moreover, a higher temperature (530–830 °C) promotes the reduction of complex compounds (i.e., acetaldehyde, methanol, propanol, and acetone), while increasing stable compounds (benzene, naphthalene, cresols, and phenols). For the case of polymer wastes, the degradation temperature ranges generally overlap or are higher than biomass, which varies between types of polymers. According to Miandad et al. [33], PP showed a single-stage degradation, which starts at a lower temperature of 240 °C with the maximum degradation at 425 °C, PS also showed a single-stage degradation but starts at a higher temperature of 330 °C, with the maximum degradation at 470 °C. While polyethylene (PE) exhibits a two-stage degradation, the first stage starts at the temperature of 270 °C and reaches 400 °C with a conversion rate of 12%, which followed by the second stage degradation starting at 400 °C, with the maximum conversion rate of 95% at 480 °C. Hence, these differences in thermal decomposition behaviours must be considered for the co-pyrolysis of biomass and polymers. According to Salvilla et al. [35], the study studied the effect of co-pyrolysis of corn stover with different polymers, i.e., LDPE, PP, and HDPE. Thermogravimetry analysis (TGA) experiments of the biomass-plastic blends result in a two-stage decomposition. The first stage involves the degradation of hemicellulose, and cellulose of the corn stover, while the second stage degradation overlaps with the decomposition of lignin. The results from this study conclude that the biomass and plastic blends exhibit the most synergistic effect occurs at temperature near 500 °C, i.e., corn stover and PP blend (5:3), and corn stover and LDPE blend (5:3) observed the greatest decomposition rate between 8% and 10% per minute respectively between the temperature ranges of 480–505 °C.

3.2.2 Heating rate

The heating rate is another important parameter that could determine the product distribution of the biofuels. According to Akhtar and Saidina Amin [31], fast heating rates cause rapid fragmentations of biomass and produces more bio-oil yield. This is possible as at higher heating rates (1000 °C·min^{-1}), there is short amount of time for the secondary reactions (i.e., tar cracking and repolymerisation). However, once the heat and mass transfer limitations have been overcome, higher heating rates would not increase the bio-oil yield further. Besides that, heating rates also affect the quality of the bio-oil, at lower heating rates, the water content of the bio-oil increases, as it impedes the dehydration reaction. It is also observed that at low heating rates (< 15 °C·min^{-1}) the bio-oil components have a higher weight range of 500–1000 Da, while increasing the heating rate to 15 °C·min^{-1}, it significantly reduces the weight to 200–500 Da. However, continuing to increase the heating rate does not reduce the weight further [75]. In the case of polymer waste, the study found that LDPE, PP, and PVC, the thermogravimetry or derivative thermogravimetry curves shifted to the higher temperatures when the heating rate was increased. This phenomenon was explained by the thermal lag, due to the increased thermal gradient between the furnace temperature and the sample. Hence, the lower 100 °C·min^{-1} heating rate favoured the degradation of the plastic wastes [60].

3.2.3 Particle size

To reduce heat transfer limitations caused by the poor heat conductivity of biomass, feedstock particle size or shape is another important criterion for bio-oil production. Larger particles (> 0.5 mm) tend to have poor heat transfer to the inner surfaces of the feedstock particle, this will lead to a lower yield of volatiles associated with the great temperature differences between the inner and outer surfaces of the feedstock particle. However, it is documented further increase in particle size (> 1 mm) does not have any effect on the bio-oil yield, which indicates minor impact of the internal heat or mass transfer to the process [76]. It was also reported that larger particle size, results in lower heat transfer to the feedstock [31,75]. For the pyrolysis of bamboo biomass with particle size, 0.45–0.75 mm, the bio-oil peaked at 54.03 wt %, while for smaller particle size 0.25–0.45 mm lowers the bio-oil yield to 50.85 wt % but increases biogas yield from 18.42 to 23.46 wt % [77]. Larger particle size of 0.8–1.2 mm, on the other hand, also lowered bio-oil yield of 51.61 wt %, with increased biogas and biochar yield of 20.62 and 27.74 wt %, respectively.

3.2.4 Residence time

Likewise, since the pyrolysis vapour is susceptible to secondary reactions, it is important to note that, the vapour residence time must be kept short to maximise the bio-oil yield. However, at very short residence times, the heat transfer limitations may restrict the feedstock from undergoing complete fragmentation [32,74,75]. Hence, the parameter is restricted by the characteristic of the feedstock itself. Instead, optimisation of the vapour residence time is a more feasible direction, i.e., feedstock particle size, heating rate, and design of the reactor and heater configuration to maximise the heat transfer [31].

3.3 The role of catalysts in the pyrolysis process

Catalysts play an important role in enhancing the quality of the bio-oil. This section categorised the existing catalysts employed in the pyrolysis process into three

main groups, commercial zeolite catalysts, metal-based catalysts, and renewable waste catalysts.

3.3.1 Commercial zeolite or acid catalyst

The commercial zeolite catalysts, i.e., ZSM-5, HZSM-5, MCM-41, zeolite Y, SBA-15, and zeolite BEA are the commonly utilised catalysts for the pyrolysis of biomass [78]. These catalysts have the active sites of the catalysts and reduce the dissociation energy of C–O, C=O, and –OH functional group, which allow the ability to remove oxygen atoms from the bio-oil via dehydration, decarboxylation, decarbonylation reactions [42,79]. Besides that, according to Ratnasari et al. [80], the key attributes of the zeolite as a suitable catalyst are the micropores (0.4–1.0 nm) or mesopores (1.5–30 nm) sizes. In a study on MCM-41, a zeolite catalyst with a mesoporous structure; the bigger pores allow hydrocarbons with higher molecular weight to enter the active sites, produce less oxygenates, and yield less aromatics. While smaller pore sized zeolites, such as ZSM-5 and Y-zeolite favour the production of aromatics. However, due to its smaller pore size, it is more likely to cause coking on the surface of these zeolites, thereby deactivating them. Therefore, studies have incorporated hierarchical catalyst structure to maximise the conversion performance [78,81]. Besides that, the acidity of the zeolites refers to the Si/Al ratio of the zeolite, it is a direct representation of the Brønsted acid (–OH group) and Lewis acid (Al sources in the Al_2O_3/SiO_2) sites available [74]. Comparing with zeolites, the silicalite catalyst with the same pore size but without acidity produces less aromatics and increases char formation [32]. Besides that, a study on the catalytic co-pyrolysis of RS and B with plastic wastes concluded that HZSM-5 promoted the deoxygenation, cleavage of the aromatic rings, reforming, isomerisation and Diels−Alder reaction of the bio-oil [22]. Hence, product upgradation was achieved, and thereby producing valuable compounds, such as aromatics (i.e., styrene, ethylbenzene, *o*-xylene, and trimethyl-benzene) and aliphatic hydrocarbons (i.e., 2,4-dimethyl heptane). Zhao et al. [82] found that, with the bamboo to PP ratio of 1:2 over HZSM-5, high bio-oil yield of 61.62 wt % can be achieved, which is higher compared to that obtained for single feedstock bamboo pyrolysis of 29.91 wt %. Besides that, the aromatic and naphthenic hydrocarbons in the bio-oil were improved, which was in agreement with the study by Suriapparao et al. [22], where with the addition of a catalyst, the biomass−plastic mixture has a lower selectivity for oxygenates, while an increase in aliphatic and aromatic hydrocarbons were observed. The findings summarising the commercial acid catalysts utilised in literature can be found in Table 4.

3.3.2 Commercial metal-based catalyst/support

The metal-based catalysts in the catalytic pyrolysis of biomass majority refers to the metal oxides, alkali earth metals, metal salts, and transition metals. Metal oxides are prominent catalysts in this case, i.e., the basic MgO, CaO, and the acidic ZnO in the study of the pyrolysis of RS. The catalytic behaviour of MgO is similar to ZSM-5, as it favours the ketonization and aldol condensation reactions, which help to reduce oxygenates from the bio-oil [75]. According to Cao et al. [83], MgO has high ionic properties, which inhibits the repolymerisation reaction, hence greatly reduces the biochar formation while increasing the bio-oil yield. Furthermore, CaO was determined to have unique properties, as it behaves differently at different mass ratio incorporated in the feedstock, at less than 0.2 mass ratios; the CaO is a reactant, that reacts with the carboxyl groups to produce ketones. Carboxyl groups are undesirable bio-oil products due to their acidity, i.e., acetic acid. At 0.2 to 0.4 mass

Table 4 Acid zeolite catalyst application in the pyrolysis process examples

Biomass	Catalyst	Bio-oil yield/(wt %)	Reactor	Scale, feed weight/g	Ref.
RS	HZSM-5	21.50	Microwave pyrolysis	200–800	[22]
Bagasse		22.40			
PP		74.20			
PS		92.30			
Baggase: PS		43.80			
B:PP		35.70			
RS:PS		31.20			
RS:PP		24.50			
RS	ZSM-5	47.40	Fixed bed reactor	10	[83]
	Y zeolite	55.20			
	Mordenite	49.10			
	SBA-15	37.30			
Rice husk and WGPF	HZSM-5/MCM41	67.90% hydrocarbon relative content	Tubular reactor	0.001	[81]
	HZSM5	60.20% hydrocarbon relative content			
Seaweed biomass	ZSM-5	51.48	Hydro-pyrolysis	10	[32]
	MCM-41	41.84			
Bamboo	HZSM-5	49.14	Bubbling fluidised bed	100 $g \cdot h^{-1}$	[77]

ratio, CaO exhibits absorbent properties, absorbing CO_2 to $CaCO_3$, which contributes to the mass increase in the char yield. A further increase of CaO (> 0.4 mass ratio), the catalytic effect dominates, reducing the ester content in the bio-oil into simpler hydrocarbons and H_2 [84]. Besides that, while ZnO has less deoxygenation properties compared to CaO and MgO, it does not increase biochar yield [32,75,85]. On the other hand, studies have also found that metal salts have effectively improved the bio-oil yield. In a study of metal salt catalysts, $MgCl_2$ produced the maximum bio-oil yield of 48.4 wt % [83], comparing to the transition metal salt $FeCl_3$, which has a lower bio-oil yield of 32.2 wt %. According to the study, the ionic behaviour of the alkali earth metal salt, $MgCl_2$ minimises the repolymerisation reaction compared to the partial covalent transition metal salts. In recent studies of the plastic pyrolysis process, the metal catalysts such as carbon-supported platinum (Pt/C), and palladium (Pd/C) were studied in the pyrolysis of PET plastic. The study aims to reduce the polycyclic compounds and biphenyls which are harmful compounds to the environment and public health. The study concludes that Pt/C aided in the reduction of polyclyclic compounds such as 2-napthalenecarboxylic acid by 102% at 800 °C, and reduction of biphenyls such as biphenyl-4-carboxylic acid by 27% at 700 °C [86]. Furthermore, metal oxides have been employed to study the co-pyrolysis process of PP with poplar wood (i.e., ZnO, CaO, MgO, and Fe_2O_3). The researchers found that CaO has the best deoxygenation results, removing carboxylic acids and phenols from the final products. It also increases cyclopentanones and alkenes compositions, but has reduced total volatile compounds, due to its strong basicity to cause coking on the catalyst surface. ZnO has the highest alkene yield, and increased ketone and phenols yields, and reduced carboxylic acid but has the weakest deoxygenation activities among all four catalysts. MgO behaves similarly to CaO, but has weaker deoxygenation properties, as it is less basic than CaO. Moreover, in the presence of the Fe_2O_3 catalyst, formation of aromatics such as *p*-xylene and 2-methyl-1-butenylbenzene were formed [87]. Following this, the studies of metal-based catalysts are summarised in Table 5, CaO is widely utilised in many studies due to its abundance and low cost, which can be found in renewable sources such as limestone and eggshells [88], and the niche in the utilisation of metal catalysts in the co-pyrolysis process.

3.3.3 Renewable waste catalyst

Renewable waste catalysts received much attention as an economic and sustainable alternative to commercial catalysts, i.e., red mud, ash catalysts, activated carbon, biochar derived catalyst, and palm oil sludge [90–94]. Red mud has attained much research interest as it has the potential to replace commercial catalyst. It is an alkaline

Table 5 Metal based catalyst application in the pyrolysis process examples

Biomass	Catalyst	Category	Bio-oil yield/(wt %)	Reactor	Scale, feed weight/g	Ref.
EFBF	CaO	Basic metal oxide	39.90 (5 wt % CaO); 40.40 (10 wt % CaO)	Fixed bed reactor	15	[85]
	MgO	Basic metal oxide	39.30 (5 wt % MgO); 42.30 (10 wt % MgO)			
	ZnO	Acidic metal oxide	44.70 (5 wt % ZnO); 42.20 (10 wt % ZnO)			
Cotton stalk	CaO	Basic metal oxide	50.00	Fixed bed reactor	–	[84]
RS	$MgCl_2$	Metal salt oxide	48.40	Fixed bed reactor	10	[83]
	$FeCl_3$	Metal salt	32.20			
	$CuCl_2$	Metal salt	41.50			
	$MnCl_2$	Metal salt	45.30			
	CaO	Basic metal oxide	38.70			
	$CaCO_3$	Basic metal oxide	30.50			
	MgO	Basic metal oxide	52.10			
	$MgCO_3$	Basic metal oxide	42.40			
	CeO_2	Acidic metal oxide	52.30			
	ZnO	Acidic metal oxide	46.20			
	ZrO_2	Acidic metal oxide	48.30			
	TiO_2	Acidic metal oxide	48.20			
EFB	CaO	Basic metal oxide	58.49	Fixed bed reactor	50	[89]
PET	Pt	Metal catalyst	–	Tube furnace	1	[86]
	Pd					
PP-poplar wood composite	ZnO	Acidic metal oxide	–	Pyrolysis-gas chromatography/mass spectrometry	0.5 mg	[87]
	CaO	Basic metal oxide				
	Fe_2O_3	Acidic metal oxide				
	MgO	Basic metal oxide				

solid by-product from the Bayer process in alumina production. According to Ly et al. [77], the components within the red mud include a great amount of metal oxides, i.e., MgO, CaO, SiO_2, Fe_2O_3, Al_2O_3, and TiO_2. From the study, red mud has a comparable bio-oil yield than HZSM-5 at temperature of 475 °C and residence time of 1.8 s. Upon characterisation of the bio-oil produced from red mud, the catalyst promoted the depolymerisation of cellulose and hemicellulose to produce furan derivatives. Besides that, the formation of saturated phenols in the bio-oil indicates red mud favours the demethylation and demethoxylation reactions. Furthermore, researchers have also studied the catalytic effect of the pyrolysis biochar. According to Dong et al. [95], the experiment on the catalytic pyrolysis of bamboo waste with different ratios of biochar, concluded that, the bio-oil had been upgraded; simpler C_2–C_6 compounds have been greatly increased with reduction in the heavy C_7–C_{11} compounds. Moreover, Chen et al. [96] proposed upgrading the biochar from the pyrolysis process such as N-doped biochar, found high yields of bio-oil (61.0–63.0 wt %) were obtainable. A study on the Fe incorporated activated carbon reduces the bio-oil yield to achieve increased phenols 60.85–86.98 wt % of the bio-oil [97]. For the pyrolysis of plastic wastes, most research utilises the low-cost fly ash and naturally occurring kaolin as renewable catalyst sources [98–100]. Furthermore, in the case of co-pyrolysis, renewable waste catalysts such as Ni-doped biochar from waste pine sawdust, and activated carbon made from coconut husks were utilized [101,102]. The summary of renewable waste catalysts is depicted in Table 6, shows that renewable waste in the literature has much lower bio-oil yields or has a higher selectivity to syngas production than commercial catalysts.

4 Kinetic analysis

Kinetic analysis is an important aspect in describing the chemical kinetics of the pyrolysis process in the form of mathematical models. Traditionally modelling the chemical kinetics of biomass pyrolysis considers cellulose, hemicellulose, and lignin, based on the TGA experimental data. These kinetic models include the iso-conversional models, the Vyazovkin method, distributed activation energy model (DAEM), and the utilisation of predictive tools, i.e., artificial neural network (ANN).

4.1 Iso-conversional models

Iso-conversional method is the simplest form of kinetic model to explain the conversion of biomass to volatiles and biochar as a one-step first-order reaction. Examples of the iso-conversional method include the Kissinger–Akahira–Sunose (KAS), Flynn–Wall–Ozawa (FWO), and Starink's method, which are integral methods ($g(a)$). In contrast, the Friedman method is an example of a differential method ($f(a)$) [104]. In this paper, Friedman and Starink's methods are chosen to demonstrate the difference between the differential and integral versions of the iso-conversional method.

4.1.1 Friedman method

Friedman method is based on the differential method as the following expression in Eq. (1). This method requires the information on the conversion rate $\frac{d\alpha}{dt}$, and T. The kinetic plots between $\ln\left(\frac{d\alpha}{dt}\right)$ and $\frac{1}{T}$ produce the slope of

Table 6 Renewable waste catalyst for pyrolysis process examples

Biomass	Catalyst	Bio-oil yield/wt %	Reactor	Scale, feed weight/g	Ref.
Bamboo	Biochar	20.20 (5 wt % biochar) 18.70 (10 wt % biochar) 16.34 (20 wt % biochar)	Microwave pyrolysis	50	[95]
Bamboo	N-doped biochar	61.00 (10 wt % biochar) 63.00 (30 wt % biochar) 62.00 (50 wt % biochar)	Fixed bed reactor	3	[96]
PKS	Fe/activated carbon	7.96	Microwave pyrolysis	10	[97]
Rice husk	Rice hull ash	–	Fixed bed reactor	0.0055	[92]
Rice husk	Coal bottom ash	–	Fixed bed reactor	0.0055	[93]
PKS	Red mud	37.37–39.95	Fixed bed reactor	2	[103]
Bamboo	Red mud	50.34	Bubbling fluidised bed	100 $g \cdot h^{-1}$	[77]
EFB	Palm oil sludge	–	Fixed bed reactor	15	[90]
LDPE	Calcinated fly ash (900 °C) Calcinated fly ash (800 °C) Natural fly ash	76.22–80.02 70.96–71.36 68.20–71.70	Semi batch reactor	50	[98]
HDPE (plastic tub pieces)	Fly ash (10 wt %)	50.84	Lab scale pyrolyzer unit	1 kg	[100]
LDPE	Kaolin (1350 mesh)	64.66% aliphatics, 93.91% hydrocarbons, 30.07% H_2	Quartz furnace tube	100	[99]
Pine sawdust and PE (50 wt %)	Ni-pine sawdust biochar	70.40 wt % (gas yield)	Fixed bed reactor	1	[101]
Corn stalk-HDPE mixture	Activated carbon	–	Tubular reactor	2	[102]

$\frac{E}{R \cdot T}$ and the intercept of $\ln[Af(\alpha)^n]$. The benefit of this model is that it makes no approximations, and can be adopted in any temperature settings [105],

$$\ln\left(\frac{\mathrm{d}\alpha}{\mathrm{d}t}\right) = \ln[Af(\alpha)^n] - \frac{E}{R \cdot T}, \quad (1)$$

where $f(\alpha)$, T, A, R, E are the differential form of the kinetic dependence function, absolute temperature (K), exponential factor (s^{-1}), universal gas constant (8.314 $J \cdot mol^{-1} \cdot K^{-1}$), activation energy ($kJ \cdot mol^{-1}$).

4.1.2 Starink's method

Starink's method is an extension of the Coats–Redfern equation (Eq. (2)), which is similar to the FWO method, an integral method for estimating kinetic parameters [105]. Since $2RT/E \leq 1$, and has minimal variation with T, results in Eq. (3),

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^2}\right) = \ln\left[\frac{A \cdot R}{E}\left(1 - \frac{2R \cdot T}{E}\right)\right] - \frac{E}{R \cdot T}, \quad (2)$$

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^2}\right) \cong \ln\left(\frac{A \cdot R}{E}\right) - \frac{E}{R \cdot T}, \quad (3)$$

where β, $g(\alpha)$ are the heating rate ($°C \cdot min^{-1}$), and the integral form of the kinetic dependence function. The generalised form Eq. (4) is

$$\ln\left(\frac{\beta \cdot g(\alpha)}{T^m}\right) = B - C\left(\frac{E}{R \cdot T}\right). \quad (4)$$

Starink's equation utilises the constants, where m = 1.92, $B = \ln(AR/E) + 3.7545411 - 1.92\ln E$, and C = 1.0008, which can be rewritten as Eq. (5),

$$\ln\left(\frac{\beta}{T^{1.92}}\right) = C_s - 1.0008\left(\frac{E}{R \cdot T}\right), \quad (5)$$

where C_s is the constant. This method is a simple direct method to obtain the expression E/R from the slopes by plotting $\ln\left(\frac{\beta}{T^{1.92}}\right)$ vs. $1/T$. Starink's method is widely employed as a comparison against other iso-conversional methods [48,106]. However, these methods are flawed, as proposed, with an addition of a secondary feedstock and the utilisation of a catalyst, the reaction mechanisms become much more complex [107]. Hence, a modified iso-conversional method is introduced, the Vyazovkin method.

4.2 Vyazovkin method

The iso-conversional methods assume a reaction ideally has a constant value of E_α. This assumption is the main source of errors, which explains the differences obtained from different iso-conversional methods [105]. Hence, to overcome these drawbacks, an advanced alternative non-linear iso-conversional Vyazovkin method is proposed. This method assumes the reaction is independent of the heating rate, and accounts for the variation of E in the computation of the temperature integral, $I(E_\alpha, T_\alpha)$ from Eq. (6). The E_α, which is the effective activation energy ($kJ \cdot mol^{-1}$) is obtained from the minimisation of the function $\varnothing(E_\alpha)$ from Eq. (7),

$$I(E_\alpha, T_\alpha) = \int_0^{T_\alpha}\left(-\frac{E_\alpha}{R \cdot T}\right)\mathrm{d}T = \frac{E_\alpha}{R}p(x), \quad (6)$$

$$\varnothing(E_\alpha) = \sum_i^n \sum_{j=i}^n \left(\frac{I(E_\alpha, T_{\alpha,i})}{I(E_\alpha, T_{\alpha,j})} \cdot \frac{\beta_j}{\beta_i}\right), \quad (7)$$

where n, E_α, T_α are the number of heating rates in the experiment, activation energy and temperature for each α, while i and j represent the heating rates corresponding to n. For $p(x)$, it is the approximation equation obtained from using Yang equation, Eq. (8):

$$p(x) = \frac{\exp(-x)}{x} \cdot \frac{x^3 + 18x^2 + 88x + 96}{x^4 + 20x^3 + 120x^2 + 240x + 120}, \quad (8)$$

where x is the simplified expression of E/RT. Hence, due to its complex structure, this model requires a numerical approach to solve for the kinetic parameters. Recent studies have started adopting this method to compute the kinetic parameters [48,54].

4.3 Distributed activation energy model

In a complex process such as co-pyrolysis, the E_α would not be constant. Instead, it varies as an indication of a much more complex reaction in place, which is unable to explain over a single-step kinetic model. The DAEM is an accurate and versatile model to represent complex pyrolysis processes. It is the best mathematical method to show the physical and chemical heterogeneity of biomass during a devolatisation process [34]. According to Hameed et al. [107], DAEM takes into consideration of the decomposition of species over a large number of independent parallel reactions with different activation energies, represented by a continuous distribution function (i.e., Gaussian distribution, $f(E)$), Eq. (9):

$$f(E) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{E - E_M}{\sigma}\right)^2\right], \quad (9)$$

where σ, E_M are the standard deviation and the mean activation energy, respectively. Furthermore, studies have simplified the DAEM based on the assumption that the solid feedstock is a complex mixture of compounds. During the pyrolysis process, a great number of independent consecutive or simultaneous, irreversible reactions take place, each characterised by its corresponding activation energies and pre-exponential factor, given by Eq. (10):

$$1 - \alpha = \int_0^\infty \exp\left(-A\int_0^t \exp\left(\frac{E}{RT}\right)\mathrm{d}t\right) \cdot f(E)\,\mathrm{d}E = \varnothing, \quad (10)$$

where, according to Cano–Pleite et al. [108], $\varnothing$ = 0.58,

which can be simplified as Eq. (11):

$$\ln\left(\frac{\beta}{T}\right) = \ln\left(\frac{A \cdot R}{E}\right) + 0.675 - \frac{E}{R} \cdot \frac{1}{T}. \quad (11)$$

However, this model is restricted to a constant heating rate. In the applications of DAEM, it has been utilised to estimate the behaviour of different combinations of lignocellulosic biomass (pine wood) and polymer wastes (i.e., waste tyre, polylactic acid, PS, PET, PP, and HDPE) [34]. Besides that, this method has been incorporated into an ANN model to predict the pyrolytic properties of *Staghorn sumac* [106].

4.4 Optimisation methods

Optimisation methods or often referred to as heuristic models, such as genetic algorithm (GA), and particle swarm optimisation (PSO), shuffled complex evolution (SCE) are algorithms that could solve global optimization problems, i.e., for the pyrolysis process, the optimisation of the kinetic parameters to find the best fit using the data from the TGA. These optimisation methods generally solve problems by subjecting it to an objective function to determine the fitness of the iterations [109]. The objective functions or optimisation targets for a thermal degradation problem are the mass loss $\varnothing_{\mathrm{m}}$ and the mass loss rate $\varnothing_{\mathrm{mlr}}$ in Eqs. (12)–(14) as follows:

$$\varnothing = \varnothing_{\mathrm{m}} + \varnothing_{\mathrm{mlr}}, \quad (12)$$

$$\varnothing_{\mathrm{m}} = \sum_{j=1}^{N}\left[W_{CML,j}\frac{\sum_{k=1}^{n}(CML_{\mathrm{mod},k} - CML_{\mathrm{exp},k})^2}{\sum_{k=1}^{n}\left(CML_{\mathrm{exp},k} - \frac{1}{n}\sum_{p=1}^{n}CML_{\mathrm{exp},p}\right)^2}\right], \quad (13)$$

$$\varnothing_{\mathrm{mlr}} = \sum_{j=1}^{N}\left[W_{MLR,j}\frac{\sum_{k=1}^{n}(MLR_{\mathrm{mod},k} - MLR_{\mathrm{exp},k})^2}{\sum_{k=1}^{n}\left(MLR_{\mathrm{exp},k} - \frac{1}{n}\sum_{p=1}^{n}MLR_{\mathrm{exp},p}\right)^2}\right], \quad (14)$$

where CML_{mod} and CML_{exp} are the model and experimental cumulative mass loss, respectively; MLR_{mod} and MLR_{exp} are the model and experimental mass loss rate, respectively; N is the number of experiments, n is the number of data points for each experiment; and W_{CML} and W_{MLR} are the weighted value which can be defined as 1.

4.4.1 Genetic algorithm (GA)

The GA is based on an evolutionary concept to find the optimal solution to a complex problem globally. Firstly, the algorithm is initialised by carrying out a range search from a set of randomised candidate solutions referred to as a population. Each candidate solution is defined as an individual or a chromosome, containing the target parameters to be optimised (i.e., for the pyrolysis process, A, E_α and $\varnothing$), where the parameters are defined as genes in the GA [109]. Following the natural survival of the fittest, the population experience evolution forming subsequent generations according to the fitness of the objective function. Besides that, the new generation is produced by the chromosomes crossing over, exchanging information, and allowing mutation, this method helps to prevent the local optimal solution. Finally, by the process of elimination of relatively "unfit" candidate solution and reproducing generations that are "fit". The application of GA in thermal degradation experiments are quite common, it is applied to solve the hybrid pyrolysis scheme of combining both parallel and convective first order reaction. Besides that, recent studies have combined it with different algorithms to improve the performance of the model, according to Aghbashlo et al. [110], the study combines GA with Adaptive Neuro–Fuzzy Interference System (ANFIS) achieving predictions of the kinetic parameters with better fitting compared to traditional ANFIS model; GA-least squares fitting procedure [111], where GA is applied to generate the initial guess for the least square function to solve for the optimal solution. This reduces the number of iterations required for the least square.

4.4.2 Particle swarm optimization (PSO)

The PSO algorithm follows the velocity and position search model. It contains a certain number of particles, their positions, and velocity. The particles in a particular position represent a candidate of solution of space, and the velocity of this particle updates the position of these particles [112]. In addition, these particles have a memory ability which, retains its historical best position vector and its global best position found [109]. Initially, the particles are assigned a random position and velocity in a proposed range. The solution then improves with iterations via Eqs. (15) and (16):

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1 r_1\left(p_{id} - x_{id}^{k}\right) + c_2 r_2\left(p_{\mathrm{g}d} - x_{id}^{k}\right), \quad (15)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}, \quad (16)$$

where k is the iteration number, i is the particle number, and d is the search direction from 1 to D, w is the inertia weight, p_{id} and $p_{\mathrm{g}d}$ are the local particle position and the global best position of all particles, respectively. c_1 and c_2 are the two positive acceleration constants for the local and global nature of the swarm. r_1 and r_2 are the stochastic values in the range of [0,1], respectively [113,114].

According to Ding et al. [109], the study compares the performance between PSO and GA, and the results indicate that PSO showed closer global optimum convergence, 0.053 at the population size of 2500 compared to GA, with the best value at 0.075 at the population size of 2000. Besides that, PSO showed less

fluctuation, 0.05 to 0.08 in fitting values regardless of population size, compared to GA, which fluctuates between 0.07 and 0.29. In literature, PSO is often coupled with other algorithms, such as global sensitivity analysis, to find the parameters with the greatest effect on the prediction outcome. According to Ding et al. [112], the sensitivity order is ranked from the largest to the smallest value which are representing the activation energy of lignin, the reaction order of cellulose, and the pre-exponential factor for lignin in the pyrolysis process of pinewood. While for the co-pyrolysis of microalgae *Chlorella vulgaris* and HDPE, the activation energy of cellulose, pre-exponential factor for cellulose and the activation energy of protein, followed by the reaction order of cellulose, showed significant influence on the prediction results, indicating these parameters should be paid much attention for the pyrolysis process [115]. Besides that, Monte Carlo simulations were applied to perform uncertainty analysis, to probabilistically assess the effects of stochastic uncertainties in the predictor values (n = 100000) from the ANN and PSO framework [113]. In addition, a recent study proposed a neuro-evolution algorithm, progressive deep swarm evolution (PDSE), built on the PSO algorithm, to model the catalytic thermal degradation of *Chlorella vulgaris* [88]. From the validation tests, implementing the PDSE algorithm obtained a coefficient of determination (R^2) value above 0.9990, RMSE below 0.0075, and MBE below 0.0026.

4.4.3 Shuffled complex evolution (SCE)

The SCE algorithm introduced by Duan et al. [116] is effective for calibration of hydrological models. The efficacy of this algorithm, a form of differential evolution (DE), comes from its use of geometric operations to find possible optimal solutions to space parameters. The algorithm solves global optimisation problems based on four concepts: (1) probabilistic and deterministic approaches; (2) clustering; (3) systematic evolution of a complex of points spanning the space in the direction of global improvement and (4) competitive evolution. The application of SCE on the woody pyrolysis was studied with six different kinetic models, comprising of single component reactant mechanism, and multicomponent reactant mechanisms (i.e., cellulose, hemicellulose, and lignin) [117]. The optimised kinetic parameters from the results were applied to predict the pyrolysis process with different heating rates, 5 and 80 °C·min^{-1}), where the results were found better fitting of the results of the multicomponent kinetic model, which can reach R^2 values of up to 0.99 [117]. Besides that, SCE has been applied in various pyrolysis kinetic analysis, pyrolysis of beech [118], and pyrolysis of basswood waste [119].

The SCE algorithm starts with generating of a population of random points within the search space, denoted as s. Each of these points contains a vector (i.e., kinetic parameters) and is ranked based on their fitness function value and stored in an array D, and partitioned into p complexes, each containing m points, i.e., $D = \{A^k, k = 1, ..., p\}$. Next, each complex evolved using the competitive complex evolution algorithm, and shuffled. All points are combined to a single population and the procedure of ranking for the function value, partition into complexes, evolution, and shuffling is repeated until convergence value is reached [116,120].

4.5 Predictive models: artificial neural network (ANN)

ANN is an intelligent learning, predictive computational technique, often employed to solve the nonlinear, and complex relationships between the input and output data. An ANN network consists of one or more hidden layers connecting the input (i) and output (o) layers. Each layer has a weight (w) matrix and an output vector [121]. The neuron of each single layer picks up the summation of the activation from the input vectors and their assigned weights and biases, the results then pass through an activation function (i.e., linear, sigmoid, and hyperbolic tangent sigmoid) to generate a new activation value to the neurons in the following layers. The weight matrix is altered to fit the learning algorithms, the learning ends when the weights of each layer achieve convergence as the final output vector (y_o) [122,123]. The ANN parameters influencing the performance are: the number of hidden layers (j), the number of neurons in each hidden layer (n), and the transfer function deployed denoted as f. The general architecture of the ANN is illustrated in Fig. 4.

Generally, the model learning process involves inputting a percentage of sample data to the network, and altering the number of neurons in the hidden layers to optimise the mean square error (MSE) [51]. Besides that, the selection is supervised by a learning algorithm. In literature, this method has been applied in predicting of the kinetic parameters of the pyrolysis process, involving the iso-conversional models, i.e., KAS and FWO shown in Table 7.

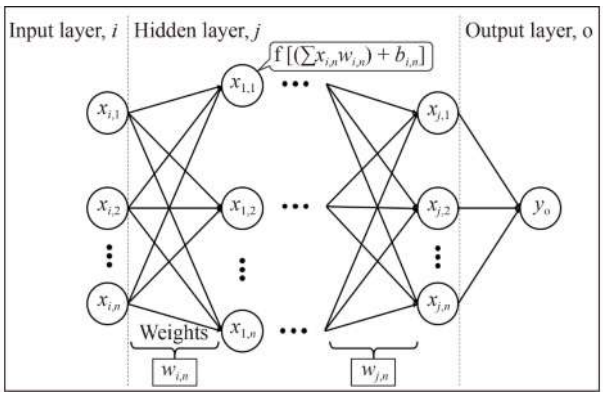

Fig. 4 General ANN architecture.

4.6 Thermodynamics relations

The thermodynamic parameters are important for the scale up and the design of the reactor, i.e., Frequency factor, A (s^{-1}), change in enthalpy, ΔH ($kJ \cdot mol^{-1}$), Gibbs free energy, ΔG ($kJ \cdot mol^{-1}$), and change in entropy, ΔS ($kJ \cdot mol^{-1} \cdot K^{-1}$). The parameters are expressed in the respective equations as Eqs. (17)–(20):

$$A = \frac{\beta \cdot E \cdot \exp\left(\frac{E}{R \cdot T_m}\right)}{R \cdot T_m^2}, \tag{17}$$

$$\Delta H = E_\alpha - R \cdot T, \tag{18}$$

$$\Delta G = E_\alpha + R \cdot T_m \cdot \ln\left(\frac{K_B \cdot T_m}{h \cdot A}\right), \tag{19}$$

$$\Delta S = \frac{\Delta H - \Delta G}{T_m}, \tag{20}$$

where T_m, K_B, h are the maximum temperature where the decomposition occurs (K), Boltzmann constant (1.381×10^{-23} $J \cdot K^{-1}$), and Plank's constant (6.626×10^{-34} $J \cdot s$) [30]. $A < 10^9$ s^{-1} refers to a simpler straightforward reaction, while $A > 10^9$ s^{-1} would mean the reaction follows a complex mechanism [129]. ΔH represents the endothermic or exothermic behaviour of the reaction mechanism; it is the amount of energy transferred during a chemical reaction. According to Gan et al. [130], the smaller the difference of ΔH with the E_α is, the more favourable for the reaction to occur. Hence, the bioenergy from the system is more likely to be attained. Moreover, ΔG is the total potential energy increased in the system, it signifies that the reactants are consumed and activated complexes are formed [21]. The ΔG also represents the suitability of the feedstock for pyrolysis, the higher the ΔG is, the more bioenergy can potentially be attained [30,51]. Furthermore, ΔS is the degree of arrangement of the carbon in the waste and biomass. It is the amount of energy unavailable to work. For higher entropy values, it indicates that the sample has yet to achieve thermodynamic equilibrium, and is highly reactive [131]. Table 8 summarises the kinetic and thermodynamic parameters for different feedstock samples.

5 Future outlooks

Many studies have proven that the combination of feedstock, biomass with waste plastic or biomass with waste tire in co-pyrolysis, with enhancements in the pyrolysis oil through synergistic effects, is an economical way for the production of sustainable fuel as a replacement for fossil fuels. The combination of waste plastics (20 wt %) with biomass generated a higher pyrolytic liquid yield compared to the solely thermal pyrolysis of biomass. This phenomenon shows that the oil produced from co-pyrolysis process can be blended with diesel after minor upgrading or even directly applied in transportation [132]. Nonetheless, not all plastic types can be applied in the process. In this sense, PVC, which consists of about 57% chlorine by weight, is not an ideal feedstock material as it will thermally break down into a very corrosive and toxic hydrochloric acid and influence the diesel quality with the production of chlorinated hydrocarbons. A 0.0145–0.0290 $mg \cdot m^{-3}$ of total chloride level has been recorded in the fuel oil product with just merely adding 1%–3% PVC in the feedstock stream [133,134]. Besides that, Hu et al. [32] stated that more studies are needed for co-pyrolysis especially in establishing a suitable approach in selecting material and the optimum blending ratio of material with biomass [32].

Furthermore, constraints in having straightforward and efficacious characterisation strategies for co-pyrolytic oil also impede the dependence of the industrial community in the technology [135]. Despite the extensive research works on the invention of the co-pyrolysis approach using

Table 7 ANN model compilation from different studies

Biomass/catalyst	Learning algorithm/ topology	Prediction result	ANN parameters	Ref.
Chlorella vulgaris limestone, HZSM-5	PDSE	Thermal degradation	Inputs: heating rate; heat flow; reactor temperature Outputs: remaining mass	[88]
Rice husk, sewage sludge	Levenberg–Marquardt (LM)	Thermal degradation	Inputs: reactor temperature; blend composition Outputs: mass loss	[21]
Chlorella vulgaris, peanut shell, microalgae ash	LM	Thermal degradation	Inputs: heating rate; reactor temperature Outputs: mass loss	[124]
Sewage sludge, peanut shell	LM	Thermal degradation	Inputs: blend compositions; heating rates; reactor temperature Outputs: remaining mass	[122]
Rice husk	Scaled conjugate gradient and LM	Thermal degradation	Inputs: heating rate; reactor temperature Outputs: remaining mass	[125]
Lignocellulosic biomass	Random forest schematic	Biochar yield	Dataset: physicochemical properties of lignocellulosic biomass	[126]
Sewage sludge	LM	HHV of syngas	Dataset: physicochemical properties of biomass	[127]
Mexican sunflower (*Tithonia diversifolia*)	LM	Bio-oil yield	Inputs: heating rate; flow rate; particle size; reactor temperature Output: bio-oil yield	[128]

Table 8 Kinetic and thermodynamic parameters of the pyrolysis process in literature

Feedstock	Catalyst	Kinetic model	E_α/ (kJ·mol^{-1})	A/ min^{-1}	ΔH/ (kJ·mol^{-1})	ΔS/ (J·mol^{-1}·K^{-1})	ΔG/ (kJ·mol^{-1})	Ref.
Pterocarpus indicus	–	Coats-redfern	112.0	–	103.0	–138.0	183.00	[35]
Intsia bijuga	–		99.0	–	89.0	–120.0	160.00	
Corn stover	–		66.0	–	57.0	–173.0	147.00	
HDPE	–		546.0	–	533.0	420.0	226.00	
LDPE	–		487.0	–	475.0	348.0	231.00	
PP	–		423.0	–	411.0	273.0	222.00	
Rice hull	–	DAEM	175.4	2.939×10^{17}	170.2	–	–	[130]
	–	FWO	177.7	7.991×10^{16}	172.6	–	–	
	Limestone	DAEM	123.3	5.803×10^{11}	117.9	–	–	
	Limestone	FWO	132.5	4.148×10^{12}	127.1	–	–	
	Eggshell	DAEM	96.1	2.033×10^{10}	90.8	–	–	
	Eggshell	FWO	100.4	1.948×10^{9}	95.2	–	–	
Sewage sludge (97.5% conversion)	–	KAS	123.6	1.440×10^{6}	119.5	139.4	187.69	[51]
	–	FWO	132.7	1.560×10^{9}	128.6	138.8	196.50	
	–	Friedman	92.4	0.0103	88.3	295.4	232.80	
	–	Popescu	200.9	9.740×10^{10}	196.8	219.3	304..00	
Microalgae:microalgae ash:peanut shell 9:2:9	–	FWO	142.6	2.010×10^{14}	137.0	–	–	[124]
Garlic husk	–	KAS	154.0	–	149.4	–	150.60	[104]
	–	FWO	154.9	–	150.4	–	150.50	
	–	Starink	154.3	–	149.8	–	150.50	
Staghorn sumac	–	FWO	167.9	–	178.9	–	–	[106]
	–	KAS	169.4	–	167.2	–	–	
	–	Starink	169.8	–	167.6	–	–	
Azadirachta indica	–	FWO	–	6.288×10^{15}	188.5	–43.3	215.40	[30]
	–	Friedman	–	8.586×10^{15}	190.9	–39.4	215.40	
	–	Vyazovkin	–	2.965×10^{20}	199.7	–26.0	215.20	
Phyllantus emblica	–	FWO	–	2.075×10^{14}	189.9	–40.9	215.30	[30]
	–	Friedman	–	2.864×10^{13}	181.3	–55.1	215.60	
	–	Vyazovkin	–	3.534×10^{13}	179.4	–58.3	215.60	
Rice husk	–	Friedman	–	–	186	–	–	[92]
	–	KAS	–	–	178	–	–	
	–	FWO	–	–	180	–	–	
	Rice hull ash	Friedman	–		148	–	–	
	Rice hull ash	KAS	–	–	148	–	–	
	Rice hull ash	FWO	–	–	146	–	–	
Chlorella vulgaris	–	KAS	156.2	2.898×10^{20}	151	–	–	[131]
	–	FWO	158.1	2.358×10^{20}	153	–	–	
	HZSM-5	KAS	145.3	2.790×10^{14}	140	–	–	
	HZSM-5	FWO	147.8	4.908×10^{14}	143	–	–	
	Limestone	KAS	138.8	6.360×10^{15}	133	–	–	
	Limestone	FWO	142.1	8.880×10^{15}	137	–	–	

different kinds of agricultural biomass and polymer wastes, the current heat transfer processes for co-pyrolysis, i.e., conduction, convection and radiation still impose several challenges. In conduction, solid attrition is the critical issue once there is a direct contact between fuel particles and heating agent. In convection, small fuel particles and long gas residence times are essential for gas/solid and sufficient heat transfer, respectively. Asymmetrically, the primary challenges of radiation are high concentration of radiation is required for the production of sufficient heat transfer and consideration of wall heating design in pyrolysis reactor [136,137]. Hence, the high installation and operating costs of units with a high efficiency of heat transfer in the short gas residence time and an additional pre-treatment system for various types of biomasses are the main drawbacks of co-pyrolysis. Different studies reported that different conditions are required to blend an appropriate waste with different biomasses before co-processing. More profound fundamental studies on reaction mechanisms and kinetics of biomass with different waste materials are critical in the advancement of the co-pyrolysis process. In this sense, the properties of the co-pyrolytic oil produced with its composition can be determined from the interactivity

of the reaction intermediates. Currently, ANN and Monte Carlo serve as empirical models that are practical in the prediction of intricate input–output interrelations in a co-pyrolysis process. However, these models are only applicable to the process and fuels, which have been well-established [21]. Co-pyrolysis kinetic datasets for predicting of product formation using different reactor systems are still fairly unexplored [135].

Moreover, the commercialisation of co-pyrolysis reactors are still in the early stages since the current reactors still have the challenges of low heat efficiency, high capital and operating costs as well as complexities with biomass handling or storage [32]. Besides that, although there is plenty of extensive research on the single feedstock pyrolysis, the feasibility study of the co-pyrolysis process remains a niche area, whereby research on the techno-economic and life cycle assessment of the process is limited to single feedstock pyrolysis, such as the co-pyrolysis of biomass refineries and the DFM layers in these references [138,139]. To the best of our knowledge, these studies for the case of co-pyrolysis are scarce, existing studies focus on the microwave co-pyrolysis of food waste and LDPE [140], and the co-pyrolysis of lignite coal with single-use plastic waste [141]. Besides that, the existing research on the modelling of the co-pyrolysis of biomass with plastic waste reaction kinetics has been widely studied, but yet to have a consensus on the reaction pathway [32].

6 Conclusions

To conclude, the recent technologies and techniques of co-pyrolysis of biomass and plastic waste to produce bio-oil have been summarised in this review. The growing agriculture industry in ASEAN countries to suit the growing population of the region, has subsequently generated landfills of biomass. To exacerbate the situation, the global pandemic gives rise to the surge of the single-use plastic waste, DMFM wastes. Fortunately, the exploitation of these wastes in co-pyrolysis would positively improve the quantity and quality of the extracted bio-oil of the process, as the result of the synergistic interactions between lignocellulosic properties of biomass and the high hydrogen content of the plastic wastes. Furthermore, the advancement of the kinetic analysis of the pyrolysis process has improved as the catalytic co-pyrolysis process becomes more complex, and unable to be explained via simple iso-conversional models. Advanced conversional models such as Vyazovkin and DAEM methods have been introduced to study the pyrolysis reaction, followed by the heuristic model and predictive models, which prove to produce high-accuracy results. However, the studies of co-pyrolysis of biomass and DMFMs remain limited. Experimental work on the binary feedstock's thermal decompositions and the bio-oil product's quantity and quality result from the co-pyrolysis has yet to be clear. The proposal of this methodology could serve as potential solution to help reduce or eliminate the pollution caused by the DMFM wastes, while producing value-added bio-oil products.

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Research papers

Expanded waste glass/methyl palmitate/carbon nanofibers as effective shape stabilized and thermal enhanced composite phase change material for thermal energy storage

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Highlights

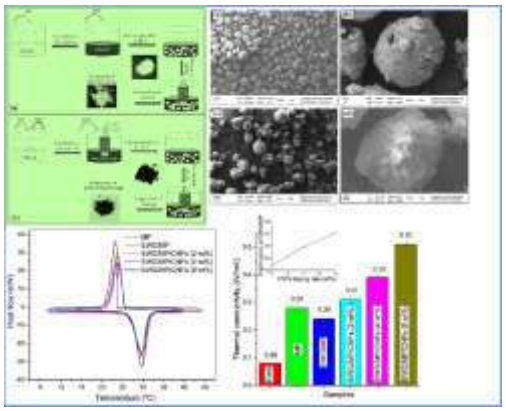
- The performance of shape stabilized PCMs with expanded waste glass and carbon nanofibers was investigated.
- Shape stabilized composites were prepared by impregnation of MP with EWG and CNFs.
- The melting temperature is in the range of 26.61-27.12°C. and melting enthalpies ranges from 96.1-96.7 J/g.
- The TGA outcomes illustrated that FSCPCM and TE-FSCPCMs had well thermal resistance.

- Thermal conductivities of FSCPCM were increased apparently especially with CNF (8 wt.%) incorporation.

Abstract

A prominent choice for phase change materials (PCMs) for passive solar thermoregulation is fatty acids because of their many beneficial characteristics for latent heat thermal energy storage (LHTES). Their low thermal conductivity and additional storage container requirements to prevent leaks during heating time, however, severely restrict their range of applications. In order to address these issues with methyl palmitate (MP) as a phase transition material, it was first doped with carbon nanofibers (CNFs) after being incorporated with expanded waste glass (EWG) using the melting/blending procedure. The SEM, XRD, FTIR, DSC, and TGA techniques were used to investigate the thermal and chemical performance of composite phase change materials (CPCMs). The leak-proof composite phase change materials (LPCPCM) and thermal enhanced shape stabilized composite phase change materials (TE-SSCPCMs) had latent energy between 96.1 and 96.7 J/g and melting temperatures between 26.61 and 27.12 °C. Doping 2, 4, and 8 wt% of CNFs into CPCMs, conductivity got enhanced by 29.2, 62.5, and 112.5% respectively, due to which, the TE-SSCPCM's charging/discharging periods were significantly shortened without changing their LHTES properties much. Further, evidence came from the thermal cycling test, TGA results, and the impressive thermal reliability, LHTES cycle performance, and chemical compatibility of all manufactured composites.

Graphical abstract



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Introduction

Due to the fact that about one-third of the world's total energy consumption occurs in buildings [1], the upgrade of resource efficiency has emerged as one of the energy technologist's primary concerns. In this context, thermal energy storage (TES) has emerged as an viable alternative methodology for addressing technology and environmental pollution issues within the last three decades [2]. PCMs and LPCPCMs with good thermal durability and performance have been deemed desirable TES components with energy storing and releasing capacity [3], [4]. The focus of several energy studies in recent years has shifted toward the creation of cutting-edge PCMs and LPCPCMs as well as the examination of their temperature control characteristics [5], [6], [7], [8], [9]. It has been found that fatty acids perform well for solar passive LHTES purposes as PCMs due to their desirable and readily available LHTES features [10], [11]. Nevertheless, direct functioning of these organic PCMs permits chemical interlinkage with the surroundings and also results in a leakage issue in solid to liquid state transition. They were enclosed in macro or micro configurations to avoid this complexity [12], [13]. However, PCM encapsulations are significantly more difficult and expensive, resulting in generally poor LHTES capacity. Combining porous, lightweight, and less costly building materials with LPCPCMs that are resistant to leakage is an alternative method. Moreover, fatty acids have a disadvantage of poor thermal conductivity (between 0.15 and 0.25W/m-K), which significantly affects their rates of phase change (heat charging/discharging) [14]. Furthermore, their incorporation into stabilized clay-based porous building matrices can result in a significant decline in conductivity. Thus, doping this type of LPCPCM with a high thermal conductive material is an effective way for boosting its thermal conductivity. Materials based on carbon such as carbon nanofibers (CNFs) [15], [16], [17], carbon nanotubes (CNTs) [18], [19], expanded graphite [20], graphite nanoplatelets (GNPs) [21], and graphene oxide [22] have primarily been used to increase the thermal conductivity of organic PCMs. CNF is a material that looks and acts like graphite. It is made by carbonating and graphitizing organic fibers. At the atomic level, each CNF is made up of thousands of small fibers that are stacked on top of each other. The carbon atoms in each fiber are organized in a hexagonal pattern. CNF had nearly the same thermal conductivity, resistance to corrosion, durability, and ability to heat energy conversion as carbon nanotubes and graphene, but it was cheaper [23], [24]. So, CNF has gotten a lot of attention as an additive to improve the properties of composite materials [25], [26], [27]. The purpose of this research is to investigate the effect of CNFs on thermal outcomes of LPCPCMs. CNF is an inorganic carbon fiber compound that can have a thermal conductivity up to 900W/m-K) in the same plane. The CNF's percolating configuration worked as a filler with significant thermal conductivity [28]. Huang et al. [16] used the 5wt% CNF in cetyl alcohol/HDPE composite which increased the thermal conductivity of composite by 1.25 times as compare to original composite thermal conductivity. Liu et al. [17] reported that the thermal conductivity of PEG/SiO2 composite was increased by 73% due to the incorporation of

3 wt% CNFs. Zhang et al. [29] boosted the thermal conductivity of erythritol as about 407.8% by incorporating CNFs by 10 wt% mass fraction. As distinct from the aforementioned literature, our aim is to develop a way to both alleviate the leakage issue and the poor thermal conductivity limitation of MP organic PCM without significantly diminishing its LHTES capability. EWG was chosen as an appropriate supporting material to eliminate the PCM's seepage problem due to its numerous positive qualities, such as its high absorption ratio, excellent thermal stability, good interfacial bonding, and long-term economic and ecological friendliness [30]. In the initial stage of the present research, MP, an organic PCM, was integrated into EWG by melting/blending process to create a new LPCPCM. Considering the poor thermal conductivities of the base materials of LPCPCM (0.28 and 0.08 W/m-K for MP and EWG, respectively), the thermal conductivity of LPCPCM was significantly enhanced by loading with CNFs at mass fractions of 2.0, 4.0, and 8.0 wt% in the subsequent phase. Using SEM, XRD, and FT-IR, the chemical and morphological features of the produced LPCPCM and TE-SSCPCMs were characterized. The impact of CNFs loading on the thermal conductivities, LHTES characteristics, thermal compatibility, and energy charging and discharging durations of manufactured LPCPCM was studied. A comprehensive study on EWG/MP/CNFs composite has not yet been published, as far as we are aware.

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Section snippets

Materials

Methyl palmitate (MP) was procured by Sigma-Aldrich company. Ethanol used as solvent was provided by Merck Company. Expanded waste glass (EWG) was purchased from Agrekal Company (Antalya-Turkey). Moreover, Carbon nanofibers (CNFs) in this work were purchased from Sigma-Aldrich Company. …

Preparation of LPCPCM and TE-SSCPCM

By using the melting/blending method, the leak proof composite PCMs (LPCPCMs), EWG/MP and EWG/MP/CNFs were created in shape stabilized form. Following the procedure shown in Fig. 1, EWG/MP was prepared as a shape …

SEM results of the prepared LPCPCM and TE-SSCPCM

Fig. 3(a-e) depicts SEM images of the EWG, FSCPCM, and TE-FSCPCM-3, which is representative of the other TE-FSCPCMs. As demonstrated in Fig. 3(a, b), the surfaces of EWG are composed of agglomerates of amorphous particles. However, these molecules have an interlinked phase picture, some of them feature holes and fissures that allow PCM molecules to be retained.

The PCM was kept uniformly within the perforations on the surface of the EWG (Fig. 3(c, d)). The CNFs with 8 wt% introduced uniformly …

Conclusions

To concurrently address the leakage problem and low thermal conductivity of MP, it was initially kept in EWG using the melting and blending technique and then loaded with CNFs. The morphology, physicochemical suitability, LHTES characteristics, conductivities, cycle TEST performances, and thermal reliabilities of LPCPCMs and TE-SSCPCMs were analyzed. The following inferences can be taken from the findings:

1. The maximum amount of MP that EWG was able to absorb was 40% by weight. Shape-stabilized …

…

CRediT authorship contribution statement

P. Singh- Writing - Original draft, Formal analysis

R. K. Sharma- Project administration, Formal analysis

Gökhan Hekimoğlu- Validation

Ahmet Sarı- Visualization

Osman Gencel- Formal analysis

V. V. Tyagi- review & editing …

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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P. Singh
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X. Zhang
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GOVERNMENT OF INDIA
Ministry of Science & Technology
Department of Science & Technology
DST/TDT/WMT/End of life Vehicles/2021/01 (G)/2
(Technology Development Transfer)

Technology Bhawan, New Delhi
Dated: **31/05/2023**

Sanction Order

Subject: Financial assistance for the project entitled **"Commercial utilization of end of life tyres to produce high value chemicals and fuel using integrated technology"** submitted by **Dr. Abhishek Sharma, MANIPAL UNIVERSITY JAIPUR, JAIPUR, MANIPAL UNIVERSITY JAIPUR, VPO DEHMI KALAN, JAIPUR 303007., 303007** Release of the **first** installment regarding

Sanction of the President is hereby accorded to the approval to the above mention project at a total cost of **Rs. 92,75,728/- (Rupees Ninety Two Lakh Seventy Five Thousand Seven Hundred Twenty Eight only)** for a duration of **3 Years Days .** The detailed breakup of the grant for General as well as Capital Components are given below:-

General Component : **₹ 76,75,728/-**
Capital Component : **₹ 16,00,000/-**

Total DST Contribution : ₹ 2336760.00/-
Total Host Institute/Industry/State Contribution : ₹ 0.00/-

	(All Institute) Budget Summary (in Rs.)			
Items	Year-1	Year-2	Year-3	Total
1- Non-Recurring				
Carbon disper grader-for analysis of carbon dispersion - 1	0	1600000	0	**1600000**
Subtotal (Capital)	0	1600000	0	**1600000**
2- Recurring				
Project Staff	1551480	1551480	1669080	**4772040**
Junior Research Fellow (JRF)-1 (01 JRF @ 31,000 + 18% HRA for 2 years and SRF @ 35,000 + 18% HRA for 3rd Year)	438960	438960	495600	**1373520**
Junior Research Fellow (JRF)-1 (01 JRF @ 31,000 + 27% HRA for 2 years and SRF @ 35,000 + 27% HRA)	472440	472440	533400	**1478280**
Senior Project Associate -1 (SPA 1 no. Rs.42,000/- + 27% HRA for 3 years)	640080	640080	640080	**1920240**
Consumables	215000	280000	170000	**665000**
Contingency	80000	80000	80000	**240000**
Travel	100000	100000	100000	**300000**
Overhead	120624	165824	162240	**448688**
Other Cost DST-	20000	500000	500000	**1020000**
Other Cost DST-	80000	100000	50000	**230000**
Subtotal (General)	2167104	2777304	2731320	**7675728**
Total Contribution (Cap.+ Gen.)	0	0	0	
Total Project Cost (Cap.+ Gen.)	2167104	4377304	2731320	9275728

Items	Budget Summary (in Rs.)			
	Year-1	Year-2	Year-3	Total
1- Non-Recurring				
Carbon disper grader-for analysis of carbon dispersion - 1	0	1600000	0	**1600000**
Subtotal (Capital)	0	1600000	0	**1600000**
2- Recurring				
Project Staff	1112520	1112520	1173480	**3398520**
Junior Research Fellow (JRF)-1(01 JRF @ 31,000 + 27% HRA for 2 years and SRF @ 35,000 + 27% HRA)	472440	472440	533400	**1478280**
Senior Project Associate -1(SPA 1 no. Rs.42,000/- + 27% HRA for 3 years)	640080	640080	640080	**1920240**
Consumables	100000	100000	170000	**370000**
Contingency	50000	50000	50000	**150000**
Travel	50000	50000	50000	**150000**
Overhead	64624	85824	100000	**250448**
Any Other (Other Cost DST)-	20000	500000	500000	**1020000**
Subtotal (General)	**1397144**	**1898344**	**2043480**	**5338968**
Total Project Cost (Cap.+ Gen.)	1397144	3498344	2043480	**6938968**

2 MANIPAL UNIVERSITY JAIPUR, JAIPUR (Dr. Abhishek Sharma)

Items	Budget Summary (in Rs.)			
	Year-1	Year-2	Year-3	Total
1- Non-Recurring				
Subtotal (Capital)	0	0	0	
2- Recurring				
Project Staff	438960	438960	495600	**1373520**
Junior Research Fellow (JRF)-1(01 JRF @ 31,000 + 18% HRA for 2 years and SRF @ 35,000 + 18% HRA for 3rd Year)	438960	438960	495600	**1373520**
Consumables	115000	180000	0	**295000**
Contingency	30000	30000	30000	**90000**
Travel	50000	50000	50000	**150000**
Overhead	56000	80000	62240	**198240**
Any Other (Other Cost DST)-	80000	100000	50000	**230000**
Subtotal (General)	769960	878960	687840	**2336760**
Total Project Cost (Cap.+ Gen.)	769960	878960	687840	**2336760**

2. The sanction of the President is also accorded to the release of **Rs. 7,69,960/- (Rupees Seven Lakh Sixty Nine Thousand Nine Hundred Sixty only)** to the **"Director/Registrar/Principal/Controller/Comptroller, MANIPAL UNIVERSITY JAIPUR, JAIPUR"** being the **first** installment of grant as mentioned above table under **"General Component"** for the above mentioned project.

3. The expenditure involved is debitable to **Demand No. 89**, Department of Science & Technology for the year **2023-24:**

3425	Other Scientific Research(Major Head)
3425.60	Others : (Sub-Major Head)
3425.60.200	Assistance to Other Scientific Bodies(Minor Head)
3425.60.200.70	Innovation,Technology Development and Deployment

3425.60.200.70.00	Detailed Head
3425.60.200.70.00.31	Grants-in-aid General
	(Previous: 3425.60.200.26.01.31)

4. The amount of **Rs. 7,69,960/- (Rupees Seven Lakh Sixty Nine Thousand Nine Hundred Sixty only)** will be drawn by DDO, DST and disbursed to the **"CNA account of Autonomous body SERB in respect of Innovation,Technology Development and Deployment Scheme".**

Name of A/C Holder	**Innovation Technology Development and Deployment**
Bank A/C No	**349902010051240**
Name of the Bank & branch	**Union Bank of India, Safdarjang Enclave - New Delhi**
RTGS/IFSC code	**UBIN0534994**

5. The amount of **Rs. 769960/- (Rupees Seven Lakh Sixty Nine Thousand Nine Hundred Sixty only)** will be drawn by the **"CNA account of Autonomous body SERB and will be disbursed to the Director/Registrar/Principal/Controller/Comptroller, MANIPAL UNIVERSITY JAIPUR, JAIPUR .** The bank details for electronic transfer of funds through RTGS are given below:-

Name of A/C Holder	**Manipal University Jaipur**
Bank A/C No	**219012010000703**
Name of the Bank & branch	**Union Bank of India**
RTGS/IFSC code	**UBIN0821900**

6. As per Rule 234 of GFR 2017, the sanction has been entered at S. No **37.** in the register of grants maintained in the **Technology Development Transfer** for the scheme **Waste Management Technologies .**

7. This issues with the concurrence of IFD vide their Concurrence Dy. No. **IFD/C/III/310523/31/00613 dated 31/05/2023.**

8. The GI will keep all the funds received in the Central Nodal Account only and shall not transfer the funds to any other account or not divert the same to Fixed Deposits/ Flexi-Account/ Multi-Option Deposit Account/ Corporate Liquid Term Deposit (CLTD) account etc. The funds released to GI shall not be parked in bank account of any other agency.

9. The GI will ensure the compliance of OM. No. F. No. **1/(18)/PFMS/FCD/2021 dated March 9, 2022** of Department of Expenditure, Ministry of Finance.

10. This sanction order is subject to the **Terms & Conditions** as annexed .

Dr. Krishna Kanth Pulicherla
(Scientist - 'E')
kkpulicherla.dst@gov.in

To,
The Pay & Accounts Officer,
Department of Science & Technology,
New Delhi – 110 016.

Copy of information and necessary action to:

1. The Principal Director of Audit, Scientific Department, IIIrd floor, AGCR Building, I.P. Estate, New Delhi.
2. The Financial Advisor, Integrated Finance Division,Technology Bhavan, New Mehrauli Road, Block C, Qutab Institutional Area, New Delhi, Delhi 110016
3. The Internal Audit Wing, Department of Science & Technology,Technology Bhavan, New Mehrauli Road, Block C, Qutab Institutional Area, New Delhi, Delhi 110016
4. Drawing and Disbursing Officer, DST, Cash Section. (two copies)
5. Dr. Abhishek Sharma, Professor, Chemical Engineering, MANIPAL UNIVERSITY JAIPUR, JAIPUR, Jaipur, Jaipur, Rajasthan - 303007
6. Dr. Rajkumar Kasilingam, Director, Material Research Center, INDIAN RUBBER MANUFACTURERS RESEARCH ASSOCIATION, Thane, Thane, Maharashtra - 400604
7. The Director/Registrar/Principal/Controller/Comptroller, INDIAN RUBBER MANUFACTURERS RESEARCH ASSOCIATION, Thane, Thane, Maharashtra - 400604

8. Dr. Anees Ahmed Yunus Khan, Assistant Professor, MANIPAL UNIVERSITY JAIPUR, JAIPUR, Jaipur Rajasthan-303007
9. Dr. Debdipta Basu, Assistant Director, INDIAN RUBBER MANUFACTURERS RESEARCH ASSOCIATION, Maharashtra-400604
10. The Director/ Registrar/ Principal/ Controller/Comptroller, INDIAN RUBBER MANUFACTURERS RESEARCH ASSOCIATION, Maharashtra-400604
11. The Director/ Registrar/ Principal/ Controller/Comptroller, MANIPAL UNIVERSITY JAIPUR, JAIPUR, Jaipur Rajasthan-303007
12. Secretary, SERB, New Delhi (for allocation of limits to implementing agency)
13. Head (Technology Development Transfer) DST
14. Sanction folder (Technology Development Transfer)

Dr. Krishna Kanth Pulicherla,
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GOVERNMENT OF INDIA
Ministry of Science & Technology
Department of Science & Technology
DST/TDT/WMT/End of life Vehicles/2021/01 (G)/2
Terms & Conditions

1. The grantee organization will furnish to the Department of Science & Technology, financial year wise Utilization Certificate (UC) in the proforma prescribed as per GFR 2017 and audited statement of expenditure (SE) along with up to date progress report (Vis-a-Vis Target Vs-Achievement) at the end of each financial year duly reflecting the interest earned / accrued on the grant received under the project. This is also subject to the condition of submission of the final statement of expenditure, utilization certificate and project completion report within one year from the scheduled date of completion of the project.

2. The grantee organization will have to enter & upload the Utilization Certificate in the PFMS portal besides sending it in physical form to this Division. The subsequent/final installment will be released only after confirmation of the acceptance of the UC by the Division and entry of previous Utilization Certificate in the PFMS.

3. If the grant has been released under capital head through separate sanction order under the same project for purchase of equipment(s), separate SE/UC has to be furnished for the released Capital head grant.

4. The grant-in-aid being released is subject to the condition that:-

a) A transparent procurement procedure in line with Provisions of General Financial Rules 2017 will be followed by the Institute/Organization under the appropriate rules of grantee organization while procuring capital assets sanctioned for the above mentioned project and a certificate to this effect will be submitted by the Grantee organization immediately on receipt of the grant.
b) While submitting Utilization Certificate/Statement of Expenditure, the organization has to be ensure submission of supporting documentary evidences with regard of the purchase of equipment/capital assets as per the provisions of GFR 2017. Subsequent release of grants under the project shall be considered only on receipt of the said documents.

5. As per the GFR 2017 Rule 230 (8) the Grantee Institute should ensure that all the interests or other earnings against Grant-in-Aid or advances (other than reimbursement) released to any Grantee institution should be mandatorily remitted to the Consolidated Fund of India immediately after finalization of the accounts. Such advances will not be allowed to be adjusted against future releases.

6. As per the GFR 2017 Rule 230 (17) "the Grantee Institute should agree to make reservations for Scheduled Castes and Scheduled Tribes or OBC in the posts or services under its control on the lines indicated by the Government of India"

7. The grantee organization will maintain separate audited account for the project and the entire amount of grant will be kept in an interest bearing bank account. For Grants released during F.Y. 2017-18 and onwards, all interests and other earnings against released Grant shall be remitted to Consolidated Fund of India (through Non-Tax Receipt Portal (NTRP), i.e. **www.bharatkosh.gov.in**), immediately after finalization of accounts, as it shall not be adjusted towards future release of Grant. A certificate to this effect shall have to be submitted along with Statement of Expenditure/ Utilization Certificate for considering subsequent release of Grant/ Closure of Project accounts.

8. DST reserves sole rights on the assets created out of grants. Assets acquired wholly or substantially out of government grants (except those declared as obsolete and unserviceable or condemned in accordance with the procedure laid down in GFR 2017), shall not be disposed of without obtaining the prior approval of DST.

9. The account of the grantee organization shall be open to inspection by the sanctioning authority and audit (both by C&AG of India and Internal Audit by the Principal Accounts Office of the DST), whenever the organization is called upon to do so, as laid down under Rule 236(1) of General Financial Rules 2017.

10. Due acknowledgement of technical support / financial assistance resulting from this project grant should mandatorily be highlighted by the grantee organization in bold letters in all publication / media release as well as in the opening paragraphs of their Annual Reports during and after the completion of the project.

11. Failure to comply with the terms and conditions of the Bond will entail full refund with interest in terms of Rule 231 (2) of GFR 2017.

12. It is mandatory to use EAT module in PFMS, failing which no further funds shall be released.

13. Goods (Consumable/Equipment) available in GeM portal are to be procured mandatorily online through GeM only as per the provisions of Rule 149 of GFR.

14. The Grantee Institute should follow Global Tendering Enquiry (GTE) conditions as per Department of Expenditure ID Note No:4/1/2021-PPD dated 10.09.2021.

15. If One time assistance or non-recurring grant as Grant-in-Aid for Rs. 10.00 lakhs to Rs. 50.00 lakhs, it should be included in the Annual Report of the Institute.

16. The Grantee Institute must ensure any other provisions of GFR-2017 and guidelines/amendments issued from Govt. of India from time to time.

अनुलग्नक

भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
विज्ञान और प्रौद्योगिकी विभाग

DST/TDT/WMT/End of life Vehicles/2021/01 (G)/2

निबंधन और शर्तें

1. अनुदानग्राही संस्थान प्रत्येक वित्त वर्ष के अंत में इस परियोजना के अंतर्गत प्राप्त अनुदान पर अर्जित/प्रोद्भूत ब्याज को विधिवत रूप से दर्शाते हुए अद्यतन प्रगति रिपोर्ट (लक्ष्य बनाम उपलब्धि) के साथ जीएफ़आर 2017 में विनिर्दिष्ट प्ररूप में वित्तीय वर्ष-वार उपयोग प्रमाण पत्र (यूसी) और व्यय का लेखापरीक्षित विवरण (एसई) विज्ञान और प्रौद्योगिकी विभाग को प्रस्तुत करेगा। यह परियोजना की समाप्ति की निर्धारित तारीख से एक वर्ष भीतर व्यय का अंतिम विवरण, उपयोग प्रमाण-पत्र और परियोजना समाप्ति रिपोर्ट प्रस्तुत करने की शर्त के भी अध्यधीन है।

2. अनुदानग्राही संस्थान को उपयोग प्रमाण-पत्र इस प्रभाग में भौतिक रूप में भेजने के साथ-साथ पीएफ़एमएस पोर्टल पर प्रविष्ट और अपलोड करना होगा। अनुवर्ती/अंतिम किस्त प्रभाग द्वारा यूसी की स्वीकृति की पुष्टि और पीएफ़एमएस में पूर्ववर्ती उपयोग प्रमाण-पत्र की प्रविष्टि के बाद ही जारी की जाएगी।

3. यदि अनुदान एक ही परियोजना के अंतर्गत उपस्कर (रों) की खरीद के लिए पृथक संस्वीकृति आदेश के माध्यम से पूंजी-शीर्ष के अंतर्गत जारी किया गया है तो जारी किया गया पूंजी-शीर्ष अनुदान के लिए पृथक एसई/यूसी प्रस्तुत करना होगा।

4. जारी किया जा रहा सहायता अनुदान निम्नलिखित शर्तों के अध्यधीन है-

क) उपर्युक्त परियोजना के लिए संस्वीकृत पूंजी आस्तियों की खरीद करते समय अनुदानग्राही संस्थान के उचित नियमों के तहत संस्थान/संगठन द्वारा सामान्य वित्तीय नियमावली 2017 के उपबंधों के अनुरूप पारदर्शी खरीद प्रक्रिया का अनुपालन किया जाए और अनुदान प्राप्ति पर तुरंत प्रभाव से अनुदानग्राही संगठन द्वारा इस आशय का प्रमाण-पत्र प्रस्तुत किया जाए।

ख) उपयोग प्रमाण-पत्र/ व्यय विवरण प्रस्तुत करते समय, संगठन को जीएफ़आर 2017 के उपबंधों के अनुसरण में उपस्कर/पूंजी आस्तियों की खरीद के संबंध में संबन्धित दस्तावेज़-साक्ष्य प्रस्तुत करना सुनिश्चित करना होता है।

5. जीएफ़आर नियमावली 2017 के नियम 230 (8) के अनुसार अनुदानग्राही संस्थान को सुनिश्चित करना चाहिए कि किसी भी अनुदानग्राही संस्थान को जारी किए गए सहायता अनुदान या अग्रिम (प्रतिपूर्ति से भिन्न) पर प्राप्त समस्त प्रकार के ब्याज या अन्य आय को लेखों को अंतिम रूप दिए जाने के तुरंत बाद भारतीय समेकित निधि में अनिवार्य रूप से विप्रेषित किया जाए। ऐसे अग्रिमों को भविष्य में जारी की जाने वाली निधियों में समायोजित करने की अनुमति नहीं दी जाएगी।

6. जीएफ़आर नियमावली 2017 के नियम 230 (17) के अनुसार, "अनुदानग्राही संस्थान को भारत सरकार के निर्देशानुसार अपने नियंत्रणाधीन पदों या सेवाओं में अनुसूचित जाति या अनुसूचित जनजाति या ओबीसी के लिए आरक्षण रखने पर सहमत होना चाहिए।"

7. अनुदानग्राही संस्थान परियोजना का पृथक परीक्षित लेखा रखेगा और अनुदान की समस्त राशि बैंक खाते में सब्याज रखी जाएगी। वित्तीय वर्ष 2017-18 के दौरान और उसके बाद जारी अनुदान के लिए, अनुदान के लिए सभी प्रकार के ब्याज या अन्य आय ऐसे लेखों को अंतिम रूप दिए जाने के तुरंत बाद भारतीय समेकित निधि में (गैर कर प्राप्ति पोर्टल (एनटीआरपी) अर्थात www.bharatkosh.gov.in के माध्यम से) विप्रेषित की जाएगी, क्योंकि यह राशि भविष्य में जारी की जाने वाली राशि में समायोजित नहीं की जाएगी। अनुवर्ती अनुदान के निर्गम/ परियोजना खाते को बंद करने पर विचार किए जाने के लिए, व्यय विवरण/ उपयोग प्रमाण-पत्र के साथ इस आशय का प्रमाण पत्र प्रस्तुत करना होगा।

8. डीएसटी, अनुदान से सृजित परिसंपत्तियों पर एकमात्र सुरक्षित अधिकार रखता है। सरकारी अनुदानों से पूरी तरह से या पर्याप्त रूप से अर्जित संपत्ति (जीएफआर 2017 में निर्धारित प्रक्रिया के अनुसार अप्रचलित और अनुप्रयोज्य, अनुपयोगी घोषित अनुदानों से इतर), का निपटारा डीएसटी का पूर्व अनुमोदन प्राप्त किए बिना नहीं किया जाएगा।

9. जैसा कि सामान्य वित्तीय नियमावली 2017 के नियम 236 (1) के तहत निर्धारित किया गया है, अनुदानग्राही संगठन का लेखा स्वीकृति प्रदाता प्राधिकरी और लेखा परीक्षक (भारत के नियंत्रक एवं महालेखापरीक्षक और डीएसटी के प्रधान लेखा कार्यालय दोनों द्वारा आंतरिक लेखा परीक्षा) द्वारा निरीक्षण किए जाने, जब भी संगठन को ऐसा करने के लिए कहा जाता है, हेतु अभिगम्य होगा।

10. इस परियोजना अनुदान से प्राप्त तकनीकी सहायता/वित्तीय सहायता की उचित पावती को अनुदानग्राही संगठन द्वारा सभी प्रकाशनों/मिडिया प्रकाशनी में मोटे अक्षरों में और परियोजना के पूरा होने के दौरान और तदुपरांत उनकी वार्षिक रिपोर्टों के शुरुआती पैराग्राफों में अनिवार्य रूप से दिखाया किया जाना चाहिए।

11. बॉन्ड के नियमों और शर्तों का पालन करने में असफल होने पर जीएफआर 2017 के नियम 231 (2) के अनुसार पूरी राशि सब्याज वापस करनी होगी।

12. पीएफएमएस में ईएटी मॉड्यूल का उपयोग करना अनिवार्य है. ऐसा न करने पर अन्य कोई भी आगामी निधि जारी नहीं की जाएगी।

13. जीएफआर के नियम 149 के उपबंधों के अनुसार जीईएम पोर्टल पर उपलब्ध वस्तुओं (उपभोज्य वस्तु /उपस्कर) का अनिवार्यतया आनॅ लाइन प्रापण जैम (जीईएम) ही के माध्यम से किया जाना है।

14. अनुदान ग्राही संस्थान को व्यय विभाग के आईडी नोट संख्या: 4/1/2021-पीपीडी दिनांक 10.09.2021 के अनुसार वैश्विक निविदाकरण जांच-पड़ताल (जीटीई) नियमों का पालन करना चाहिए।

15. यदि एकबारगी सहायता या गैर-आवर्ती अनुदान 10.00 लाख रुपये से 50.00 लाख रुपये के सहायता अनुदान का हो तो इसे संस्थान की वार्षिक रिपोर्ट में दर्ज किया जाना चाहिए।

16. अनुदान ग्राही संस्थान को जीएफआर-2017 के किसी भी अन्य उपबंध और समय-समय पर भारत सरकार द्वारा जारी दिशा-निर्देश/संशोधन का अनुपालन सुनिश्चित करना चाहिए।

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