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RESEARCH ARTICLE

Spatial analysis of flash flood and drought impact from climate change in Phongsaly district, Phongsaly province, by using Geo-Informatics technology and Modelling

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Abstract
A method for predicting the water resource in the region in the future to be used as a basis for mitigating the consequences is to study how climate change affects hydrology. The purpose of this study is to i). choose a global climate model that is suitable for the area, ii). rainfall run-off modelling, iii). drought and flood hazard index map. The SSP-126, SSP-245, and SSP-585 scenarios were chosen as the most appropriate global climate model among the four institutes, with efficiency criteria using the coefficient of Nash-Sutcliffe and Kling-Gupta and then calibrate the data with the Bias Correction Linear Scaling method which divides the analysis period into 2 periods for Near-Future and Far-Future from analyzing Rainfall Run-off Modeling from Rainfall Concentration 1-hours, 3-hours and 6-hours. It was found that the SSP-585 scenario in the Rainfall Concentration 1-hours model has the most dangerous area for very high risk until the end of the 21st century. For the analysis of drought indices SPI_1, SPI_3 and SPI_6 in Near-Future, it was found that the frequency of droughts is increasing according to the worst scenario, the scenario with the most drought is SSP-585 and in the Far-Future, the frequency of drought is decreasing according to the worst scenario, the scenario with the most drought is SSP-126.

Keywords: Drought; Flood; Flash flood; Model; Climate change; IPCC

Introduction

In late 2021, the IPCC released its Sixth Assessment Report (AR6), detailing the rise in global temperatures to 1.5℃ Inevitably above pre-industrial levels, Floods and landslides are quite likely across Asia, and the continent's temperatures will rise. by proposing a new method for projecting greenhouse gases by bringing Shared Socioeconomic Pathway (SSP) applying a prediction to the end of the 21st century in 5 scenarios: (IPCC, Climate Change 2021: The Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report, 2021).

- SSP1-1.9: A 1.5 °C temperature rise by 2050.
- SSP1-2.6: A 1.8 °C temperature rise by 2100.
- SSP2-4.5: A 2.7 °C temperature rise by 2100.
- SSP3-7.0: A 3.6 °C temperature rise by 2100.
- SSP5-8.5: A 4.4 °C temperature rise by 2100.

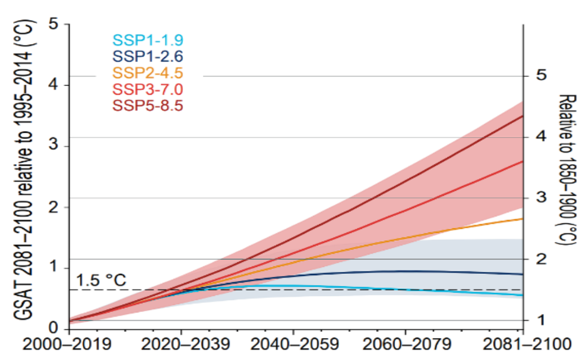


Figure 1. The graph shows the temperature increase in each scenario.

According to the Lao Green Climate Fund (GCF) Work Plan, Lao PDR has emitted 52,790Gg CO2eq of greenhouse gases into the atmosphere, of which 82% of total emissions come from land use change. In addition, after 2009, Lao PDR is prone to floods and droughts, especially in the northern region, which often experiences flash floods. (GCF, 2021)

Lao PDR is a landlocked country. but has much more natural resources than many Asian nations, particularly in the areas of water, forests, and minerals. In 1940, the Lao PDR had 70% of its land covered in forests, but by 2002, that number had decreased to 41.5% (UNDP, 2012), making Lao PDR the 42nd most vulnerable country to climate change.

One of these is Phongsaly Province in the north of Lao PDR, which regularly experiences flash floods and droughts. Lao PDR is thought to be the country most susceptible to drought. because rivers and streams are where most people reside. The primary industry is agriculture. (ADB, 2012)

According to the Mekong River Commission's (MRC) Measuring Station's observational monitoring data for the years 2020–2022, the Phongsaly District experienced 40 droughts in total, including 9 severe, 5 extreme, and 1 catastrophic drought, the most of which took place between the July to December. (MRC, 2019)

Additionally, one of the Sustainable Development Goals (SDGs), the 13th goal with a plan to address it, includes addressing climate change (Climate Action).

In the scenario, it serves as a guideline for planning, mitigating, and adapting to climate change, as well as for resolving issues and creating a development plan for the Lao PDR to lessen the effects of potential disasters like floods and droughts brought on by the worsening severity of climate change. Additionally, it tries to adjust development strategies in accordance with the scenario and increase awareness of the severity of the issue. Therefore, we are interested in using geographic information systems and models to analyze the places in Phongsaly District and Phongsaly Province that have experienced floods and droughts because of climate change.

Literature review

Several studies have looked at global climate change issues, but in Lao PDR, there are still few regional studies. Phrakonkham, Khasama, et al. (2020), integrated and mapped hazards using the Analytical Hierarchy Process (AHP) across Laos. From the results of the study, it was found that hazard areas are distributed in the northern and southern regions of Lao PDR. Rasanak, Sanxay et al. (2021) studied the impact of climate change by using the CMIP5 global climate model and rainfall runoff model to map flood hazard areas in the Xedon basin in the southern part of Lao PDR. From the results, the most high-hazard area found in the far future, the RCP8.5 scenario, covers an area of 483.9 km2. Maisor et al. (2022) used the CMIP6 global climate model by making a flood hazard map in the Xechamphone Basin in the central region of Lao PDR. From the results of the study, it was found that in the near future, the SSP126 scenario has the most area of very high hazard, and in the near future, the SSP585 scenario has the most area of very high hazard. from earlier studies Natural disasters and climate change continue to have an adverse impact on many regions. There is still no regional climate change analysis in the northern part of Lao PDR, which is essential for planning mitigation strategies.

Methodology

Study area

The capital of Phongsaly Province, Phongsaly District, has a total area of 2,855 km2 and is located at latitude and longitude 208962 and 2419580, respectively, between (Zone) UTM 47 and 48N. It has a main river named Nam Ou and is the highest city in the Lao PDR; its northern border is with China, its southern border is with Xay District in Oudomxay Province, and its eastern border is with Thailand. Additionally, Phongsaly District has a favorable climate for agriculture and produces agricultural goods.

Phongsaly District, Phongsaly Province, is reportedly one of the regions that has suffered disasters every year for the previous ten years or more, according to reports from various organizations. together with the issue of climate change that the world is currently facing. As a result, we decided to research this issue's consequences to develop guidelines for avoiding and lessening its negative effects.

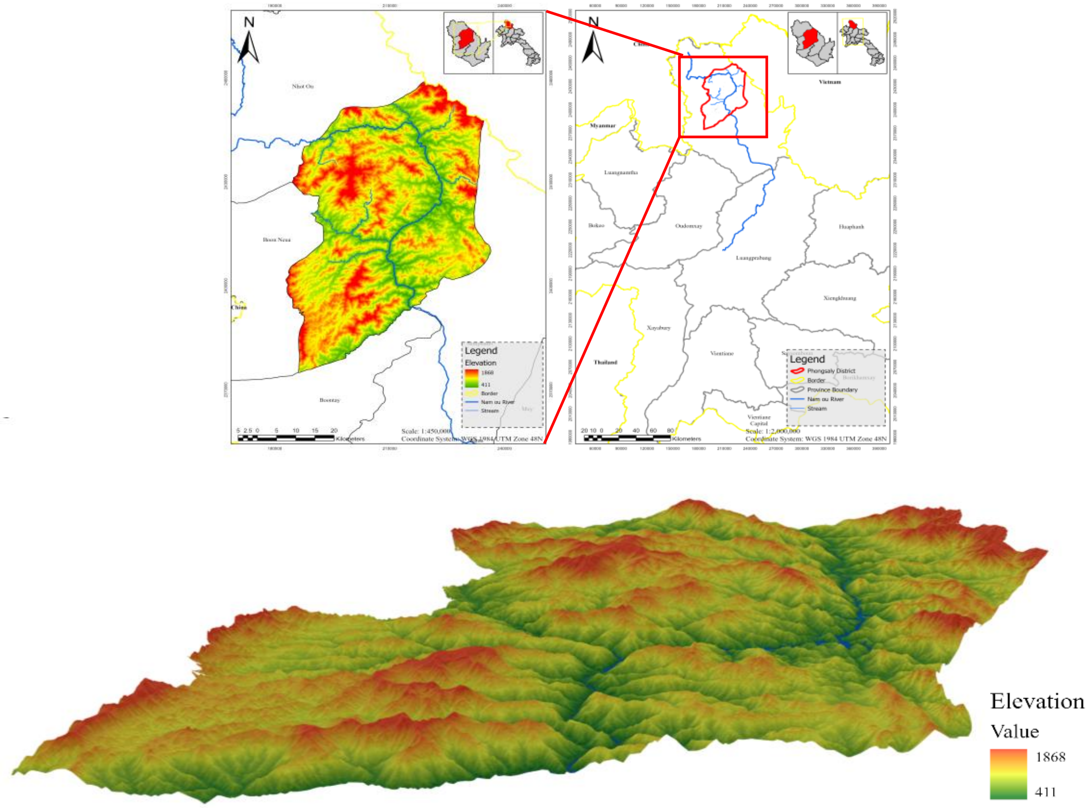


Figure 2. Map showing study area, elevation, and topography of Phongsaly Province.

For this study, we divided the analysis period into two time periods: the near future from 2018 to 2050 and the far future from 2051 to 2100, and daily rainfall data for a 21-year period (1997-2017) was collected from four stations in the Nam Ou catchment area, namely Phongsaly, Muong Ngoy, Dien Bien and Oudomxay. Refer to the data from the Mekong River Commission (MRC) rain gauge stations as shown in the table below. This historical data will be interpolated in an area with a resolution of 12.5 x 12.5 m by using the Inverse Distance Weight (IDW) technique. Global climate models by using downscaling techniques and adjusting data predictions to be as close to reality as possible. The most appropriate Global climate models were then selected for use in the analytical study.

Table 1. Rain gauge station used in this study.

No	**Rain Gauge Station**	**Station ID**	**Time Intervals**	**Coordinate (UTM)**		**Source**
				X	**Y**	
1	Phongsaly	210201	1922-2019	210505	2406007	
2	Dien Bien	210301	1979-2022	293236	2363995	Mekong River Commission (MRC)
3	Muong Ngoy	200201	1996-2017	259051	2290796	
4	Oudomxay	200204	1984-2019	810792	2289916	

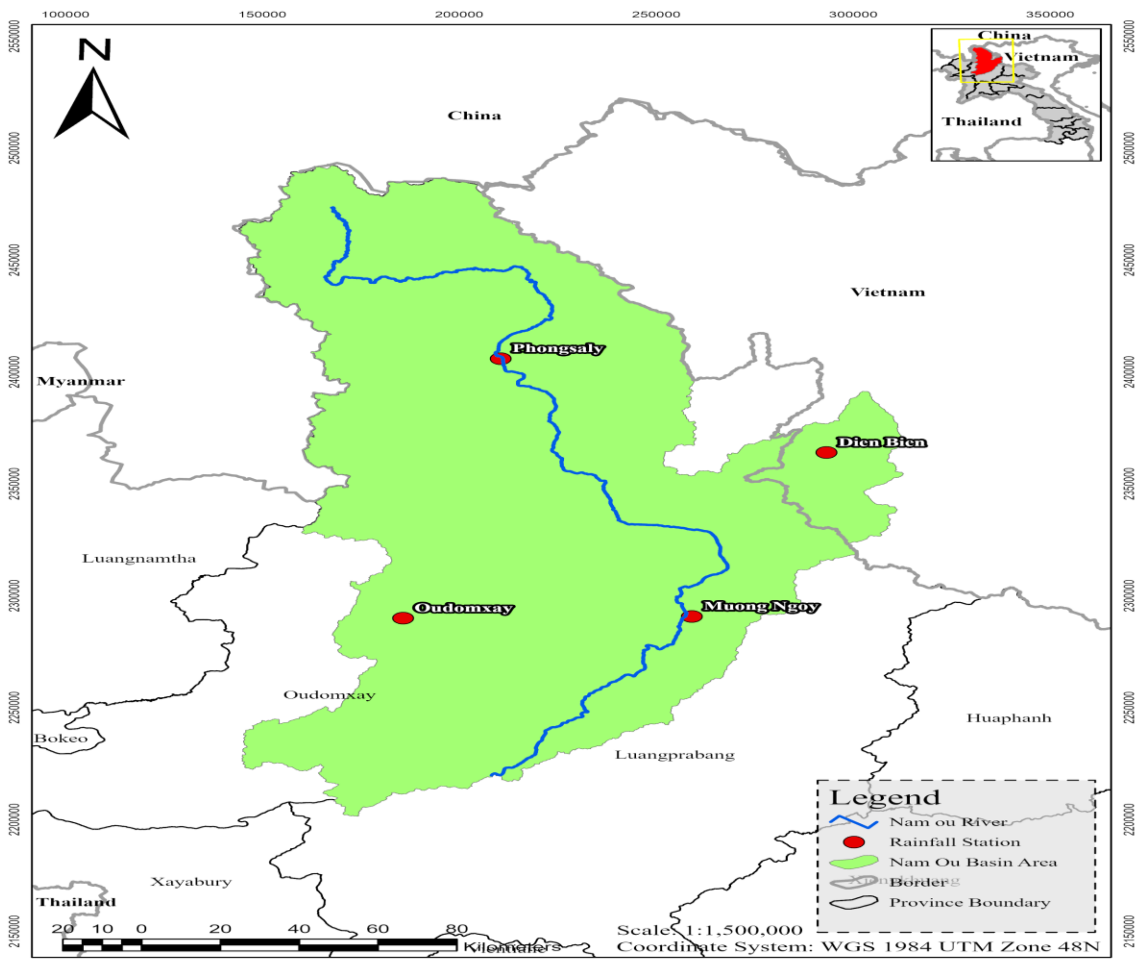


Figure 3. Map showing location of rain gauge station.

For simulated data collection, we rely on global climate models (GCMs) from four institutes. The 4 models are: the Institute Pierre Simon Laplace, France (IPSL), the Max Planck Institute for Meteorology, Germany (MPI), the Meteorological Institute, Norway (NorESM), the National Institute for Environmental Studies, and the Japan Agency for Marine-Earth Science and Technology, Japan (MIROC). which has forecast the rainfall data from now until the end of the 21st century, which is detailed in the table below:

Table 2. Global Climate Models are used in this study.

No	GCMs	Institute	Frequency	Resolution
1	IPSL-CM6A-LR	Institute Pierre Simon Laplace, France	day	2.5˚x 1.3˚
2	MPI-ESM1-2-LR	Max Planck Institute for Meteorology, Germany	day	1.9˚x 1.9˚
3	NorESM2-LM	Meteorological Institute, Norway	day	2.5˚x 1.9˚
4	MIROC6	National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	day	1.4˚x 1.4˚

Extract time series

The four institutes' climate models have different data sets. Therefore, we write a coding algorithm to retrieve data from specific global climate models using Python. So, we merged the files into one file first. and then retrieve information in the area we study.

Performance indicator

Nash-Sutcliffe efficiency (NSE)

Nash-Sutcliffe efficiency (NSE) (J.E. Nash, 1970) It is a popular index used to determine model accuracy or model performance. To estimate the desired value with the following formula:

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}(Y_i - \widehat{Y}_l)^2}{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}$$

Where

Y_I: The observed value of I when I is between 1 and n.

$\widehat{Y}_I$: Prediction value Y_i

$\overline{Y}$: Mean value of Y_i

NSE have a value between -∞ to 1 Which can interpret the meaning of the NSE value as shown in the table below:

Table 3. Meaning of NSE value.

NSE Value	Model Accuracy
1	Perfect Fit
>0 - <1	Arithmetic Mean
0	The model can predict the values as accurately as the prediction using the mean.
<0	The model can predict with less accuracy than the mean estimate.
≥0.75	Good prediction (Yangqing Lian, 2007)
0.36 – 0.75	Satisfactory prediction (Yangqing Lian, 2007)

Kling-Gupta efficiency (KGE)

This measure of fit was created by (Hoshin V. Gupta, 2009) to aid Nash-Sutcliff performance categorization analysis. This makes it easier to evaluate the relative significance of the variables (correlation, bias, and variance) within the context of a hydrological model (Harald Kling, 2012), whose equations are as follows:

$$\mathrm{KGE} = 1 - \sqrt{(\mathrm{CC}-1)^2 + (\frac{\mathrm{cd}}{\mathrm{rd}} - 1)^2 + (\frac{\mathrm{cm}}{\mathrm{rm}} - 1)^2}$$

Where

CC: Pearson Coefficient

rm: Average of Observed values

cm: Average of Forecast values

rd: Standard Deviation of Observation values

cd: Standard Deviation of Forecast values

The Pearson coefficient can be obtained from the equation below:

$$r = \frac{\sum_{i=1}^{n}(O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \overline{O})^2}\sqrt{\sum_{i=1}^{n}(P_i - \overline{P})^2}}$$

Where

O_i: Observation value

P_i: Prediction value

$\overline{O}$: Mean value of O_i

$\overline{P}$: Mean value of P_i

Calibration

Large geographic resolution data are available from global climate models for precipitation forecasts. The data must be adjusted using Linear Scaling Bias Correction (LS) before using [9]. LS is a simple statistical estimating approach utilized in numerous investigations.

$$P_{his}(d)^* = P_{his}(d) \cdot [\mu_m\{P_{obs}(d)/\{\mu_m P_{his}(d)\}]$$

$$P_{sim}(d)^* = P_{sim}(d) \cdot [\mu_m\{P_{obs}(d)\}/\{\mu_m P_{his}(d)\}]$$

Where

P_{obs}: Observation data

P_{his}: Historical data from GCMs

$P_{his}{}^{*}$: Historical data from GCMs after Bias correction

$P_{sim}{}^{*}$: Precipitation data from GCMs after Bias correction

P_{sim}: Precipitation data from GCMs

d: Precipitation data

μ_m: Correction factor

Return period

To estimate the probabilities of total monthly rainfall and to estimate rainfall around the recurrence of total monthly rainfall in this research, we used a method (Weibull, 1939) to obtain a frequency of exceedance that is closest to the mean value of the distribution, with the following formula:

$$P = \frac{N}{(m+1)}$$

Where

P: Probability of exceedance

N: Total number of years record

m: Rank of observed rainfall value

T: Return period (mm) given by $T = \frac{1}{P}$

Standardized precipitation index (SPI)

(Thomas B. McKee, 1993) developed the SPI method to determine and monitor climate drought conditions, which is now used by various organizations. It is widely used to analyze the SPI index from monthly rainfall. The SPI will be analyzed over 3 periods, namely 1 month, 3 months, and 6 months, which this research will define as SPI_1, SPI_6, and SPI_12, respectively.

$$SPI = \frac{X_{ij} - X_{im}}{\sigma}$$

Where

X_{ij}: Precipitation for the station i month j (mm)

X_{im}: Mean precipitation (mm)

σ: Standardized deviation

The criteria used by the SPI to categorize drought levels are listed in the table below:

Table 4. Drought Classification based on SPI (McKee et al., 1993)

Drought classes	SPI
≥ 2	Extremely wet (EW)
1.50 to 1.99	Very wet (SW)
1.00 to 1.49	Moderately wet (MW)
-0.99 to 0.99	Near normal (N)
-1.00 to -1.49	Severely dry (MD)
-1.50 to -1.99	Severely dry (SD)
≤ -2	Extremely dry (ED)

Flood hazard index classification

By considering the flood depth of each square in the flood map and converting it to a value is a disaster index, we proposed the hazard level with a flood disaster index adjusted for the relationship between flood depth and velocity (Sally J. Priest, 2009), as shown in the table and figure below;

Table 5. Flood depth-hazard index relationship**.**

Flood depth (m)	Hazard index
Small hazard < 0.3	0.00 – 0.25
Medium hazard < 0.6	0.25 – 0.50
High risk < 2	0.50 – 0.75
Very high risk > 2	0.70 – 1.00

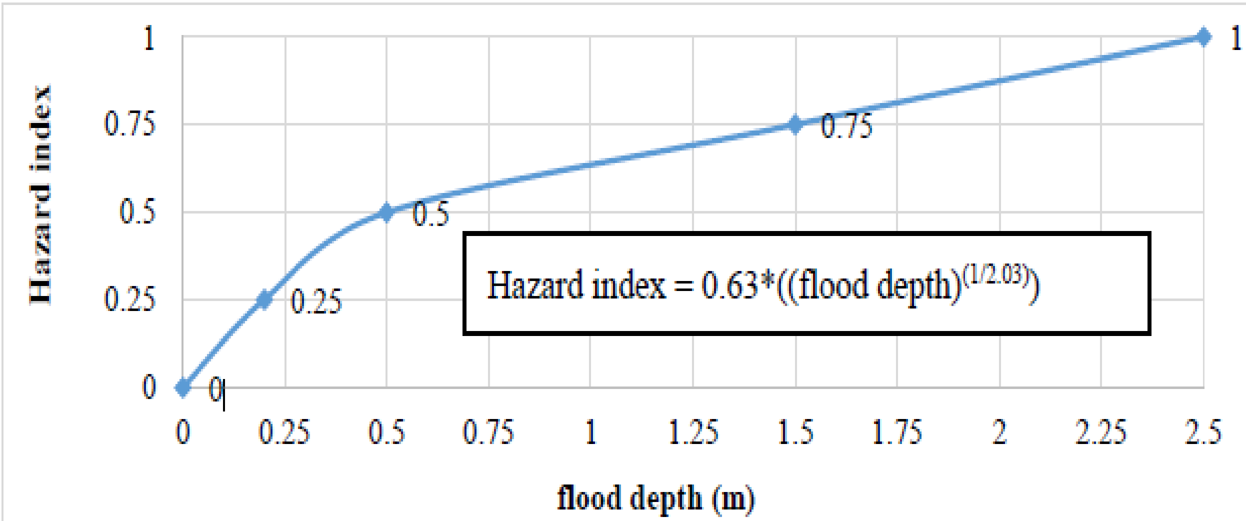


Figure 4. Flood depth and hazard index relationship curve.

Results and discussions

Performance indicator

Using observed rainfall data from five stations in the watershed area and historical data from four GCMs, a performance indicator was developed using Nash-Sutcliffe and Kling-Gupta. From the result of the distribution of monthly rainfall with observed and simulated data, in most cases the simulated data is much less than the actual observed data, but in most cases the sample is close to the actual rainfall data.

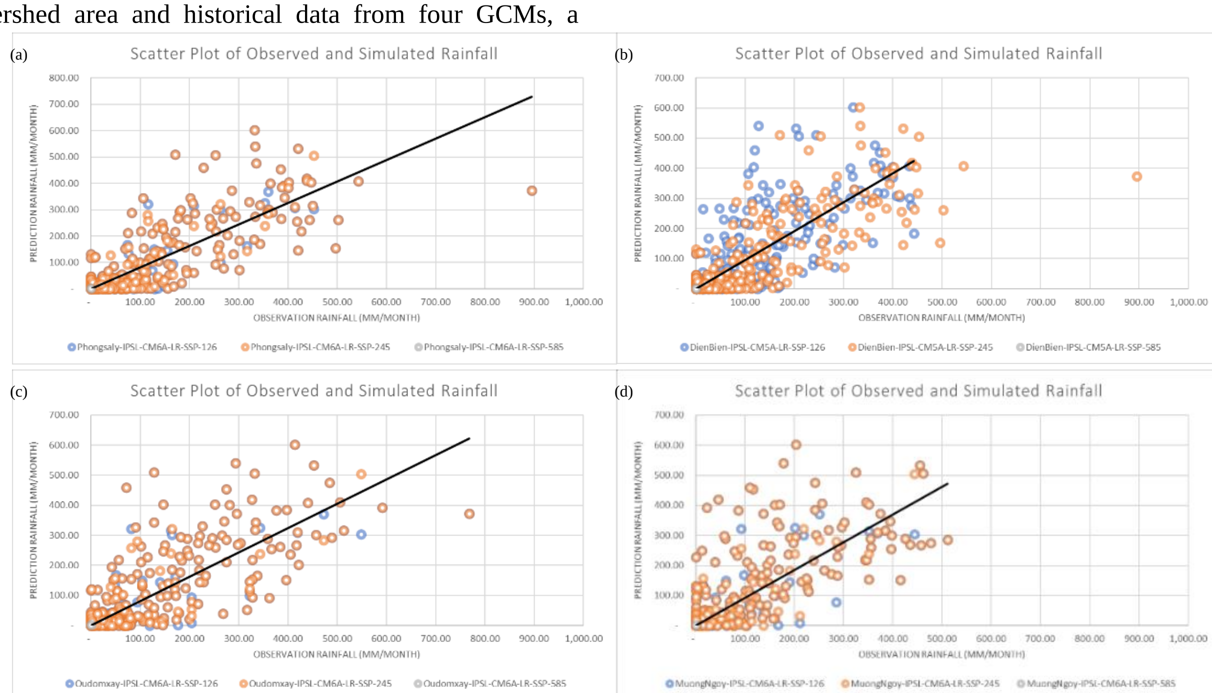


Figure 5. Scatter plot of observed and simulated data: (a) Phongsaly-IPSL-CM6A-LR, (b) DienBien-IPSL-CM6A-LR, (c) Oudomxay-IPSL-CM6A-LR and (d) MuongNgoy-IPSL-CM6A-LR.

The IPSL-CM6A-LR, which has an average coefficient primarily near 1, is the model that is most suitable according to Nash-Sutcliffe and Kling-Gupta performance indicator, which also places the MPI-ESM1-2-LR, MIROC6, and NorESM2-M next.

Table 6. Efficiency value of Nash-Sutcliffe and Kling-Gupta.

Nash-Sutcliffe Efficiency												
Rainfall Station	**Predicted Rainfall**											
	IPSL-CM6A-LR			**MIROC6**			**MPI-ESM1-2-LR**			**NorESM2-M**		
	SSP126	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**
Phongsaly	0.553	0.558	0.564	0.367	0.343	0.380	0.406	0.416	0.404	0.259	0.250	0.261
DienBien	0.552	0.552	0.554	0.379	0.354	0.381	0.605	0.630	0.624	0.293	0.285	0.281
Oudomxay	0.478	0.477	0.452	0.332	0.277	0.358	0.457	0.487	0.487	0.207	0.191	0.201
Muong Ngoy	0.493	0.513	0.527	0.361	0.324	0.375	0.627	0.646	0.642	0.203	0.194	0.189
Average scenario	**0.519**	**0.525**	**0.524**	**0.360**	**0.324**	**0.374**	**0.524**	**0.545**	**0.539**	**0.241**	**0.230**	**0.233**
Average GCMs	**0.52**			**0.35**			**0.54**			**0.23**		
Kling-Gupta Efficiency												
Rainfall Station	**Predicted Rainfall**											
	IPSL-CM6A-LR			**MIROC6**			**MPI-ESM1-2-LR**			**NorESM2-M**		
	SSP126	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**
Phongsaly	0.74	0.74	0.747	0.66	0.64	0.65	0.56	0.56	0.56	0.63	0.62	0.63
DienBien	0.65	0.65	0.65	0.58	0.57	0.58	0.66	0.69	0.68	0.49	0.48	0.48
Oudomxay	0.67	0.66	0.65	0.62	0.60	0.62	0.62	0.63	0.63	0.60	0.59	0.59
Muong Ngoy	0.63	0.64	0.65	0.59	0.57	0.59	0.66	0.66	0.66	0.50	0.50	0.50
Average Scenario	**0.675**	**0.674**	**0.673**	**0.61**	**0.59**	**0.61**	**0.62**	**0.63**	**0.63**	**0.55**	**0.55**	**0.55**
Average GCMs	0.67			0.60			0.63			0.55		
Average Efficiency	**0.60**			**0.48**			**0.58**			**0.39**		

Model calibration

The observed precipitation data over a 21-year period was used in a bias correction process with historical data from the IPSL-CM6A-LR based on scenarios SSP-126, SSP-245, and SSP-585. The analysis found that the historical data was lower than the observed rainfall. But in some scenarios, it's the opposite. which is shown in the cumulative distribution curve as follows:

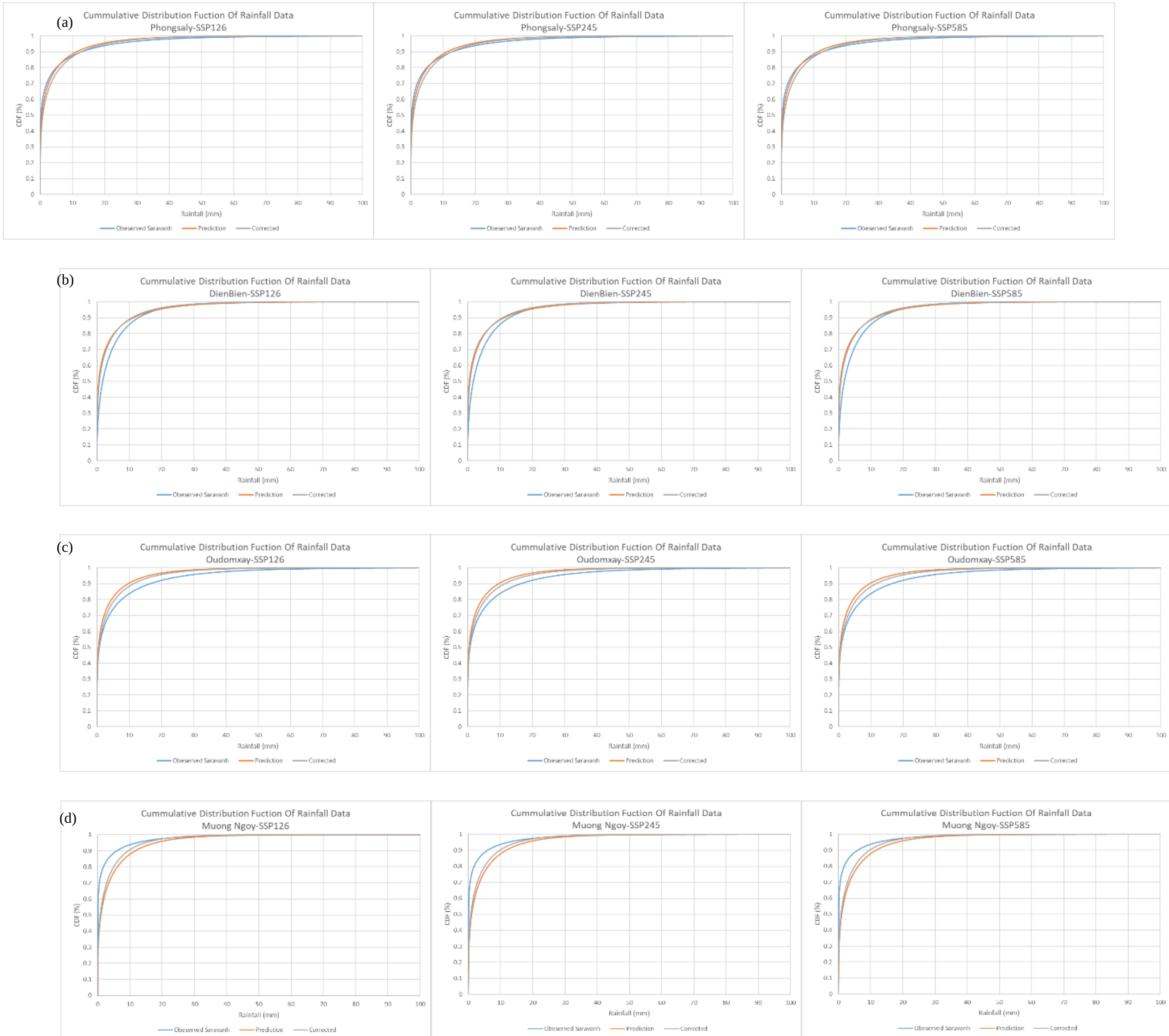


Figure 6. Cumulative distribution function of rainfall data at rainfall stations (a) Phongsaly, (b) DienBien, (c) Oudomxay, and (d) Muong Ngoy based on each scenario.

Flood hazard

1 Hour concentration interval

In the near future, the area prone to very high-risk flooding under the SSP-126 scenario is 87.13 km^2, the SSP-245 scenario has an area of 160.73 km^2, an increased from the SSP-126 scenario of 84.46%, and the SSP585 scenario has an area of 180.20 km^2, an increased from the scenario in SSP-245 by 12.11%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

In the far future, the area prone to very high-risk flooding under the SSP-126 scenario is 170.95 km2, the SSP-245 scenario has an area of 168.90 km2, a decreased from the SSP-126 scenario of -1.20%, and the SSP585 scenario has an area of 171.08 km2, an increased from the scenario in SSP-245 by 1.29%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

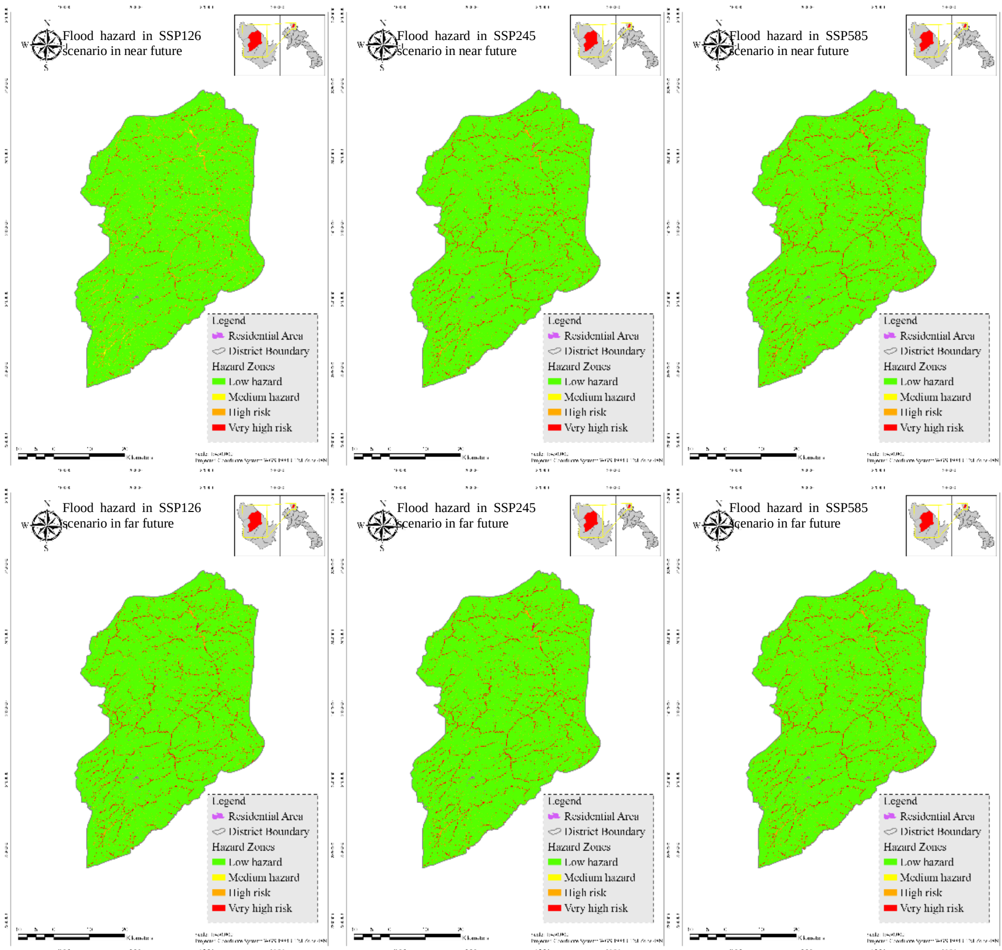


Figure 7. Flood hazard map in 1 hour's concentration of rainfall for each scenario.

Table 7. Flood hazard area in 1 hour's concentration of rainfall for each scenario.

1 Hours Concentration Interval Flood Hazard Area (km^2)							
No	**Hazard Zones**	**Near Future**			**Far Future**		
		SSP126	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**
1	Low hazard	2627.25	2630.79	2613.99	2622.64	2624.57	2622.53
2	Medium hazard	36.49	9.83	9.87	9.96	9.88	9.98
3	High risk	99.97	49.50	46.78	47.29	47.50	47.25
4	Very high risk	87.13	160.73	180.20	170.95	168.90	171.08

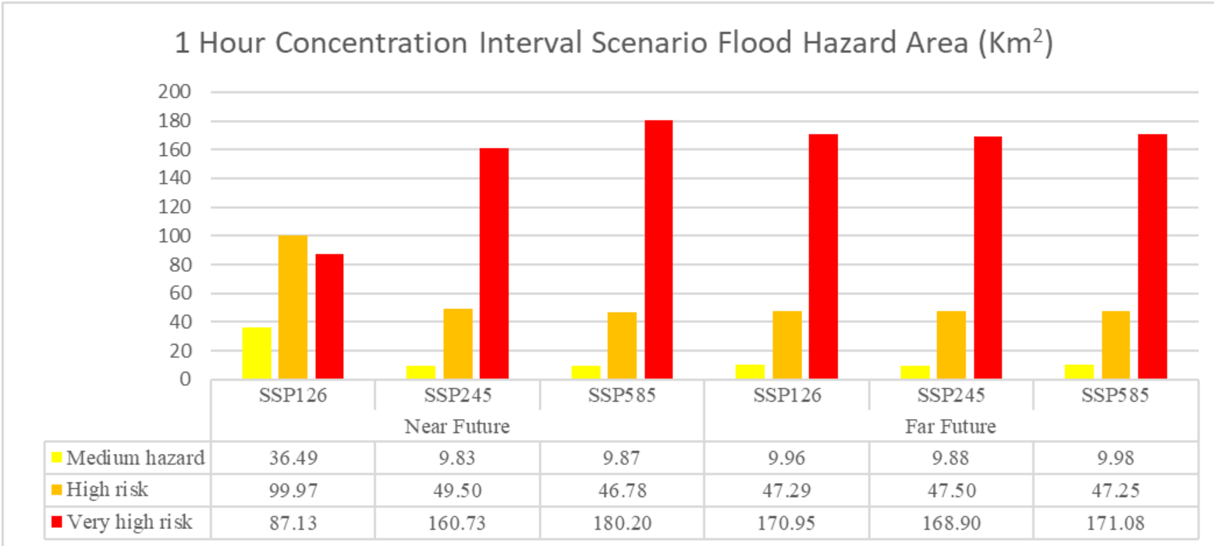


Figure 8. Graph showing comparison of the area in 1 hour's concentration of rainfall for each scenario.

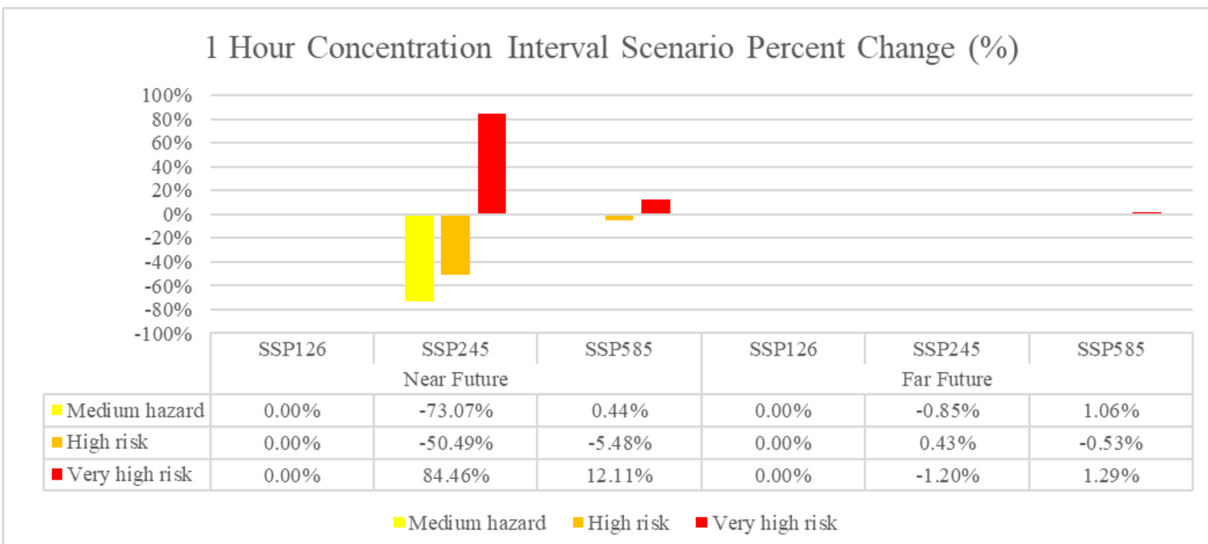


Figure 9. Graph showing the percent change in area in 1 hour's concentration of rainfall for each scenario.

3 Hour concentration interval

In the near future, the area prone to very high-risk flooding under the SSP-126 scenario is 160.69 km^2, the SSP-245 scenario has an area of 158.12 km^2, a decreased from the SSP-126 scenario of -1.60%, and the SSP585 scenario has an area of 170.01 km^2, an increased from the scenario in SSP-245 by 7.52%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

In the far future, the area prone to very high-risk flooding under the SSP-126 scenario is 165.70 km^2, the SSP-245 scenario has an area of 164.56 km^2, a decreased from the SSP-126 scenario of -0.69%, and the SSP585 scenario has an area of 165.74 km^2, an increased from the scenario in SSP-245 by 0.72%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

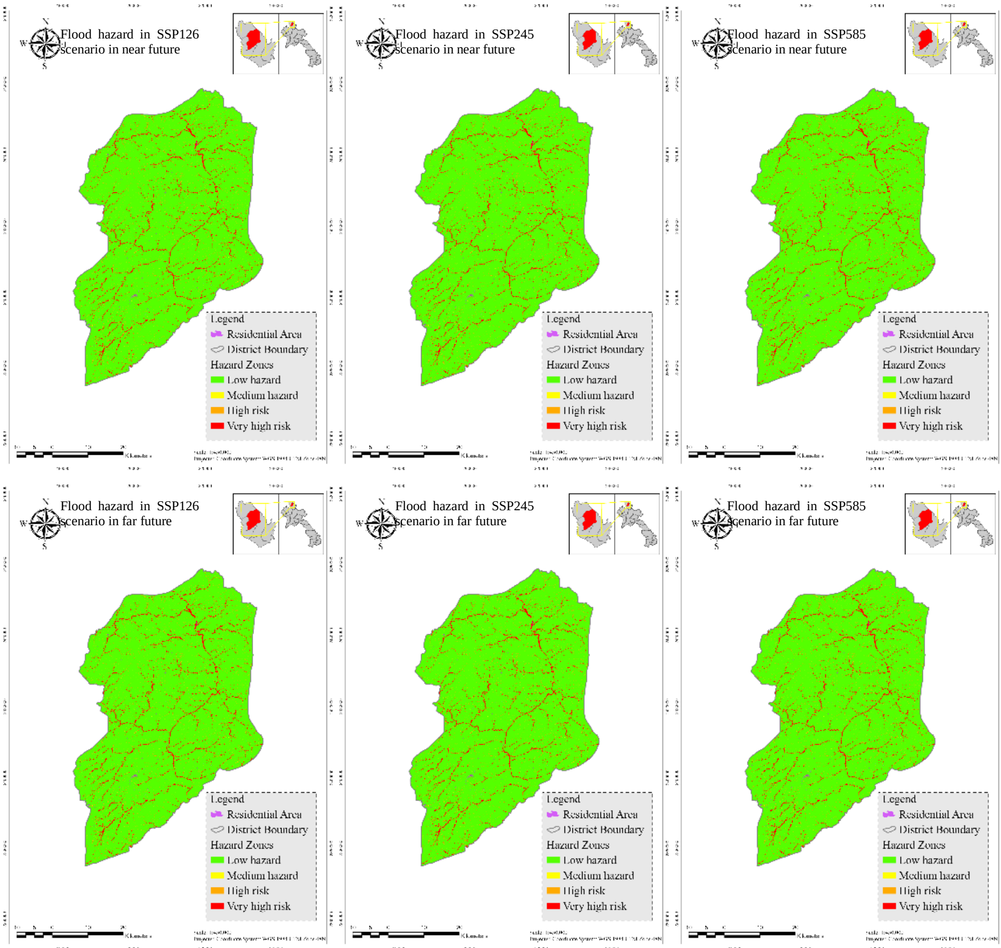
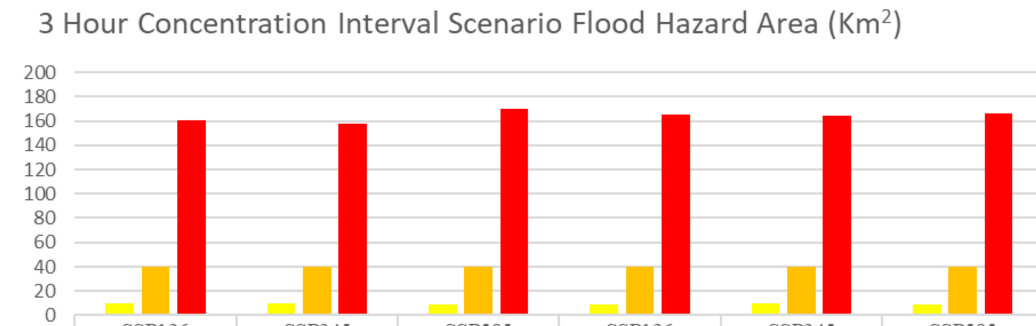


Figure 10. Flood hazard map in 3 hour's concentration of rainfall for each scenario.

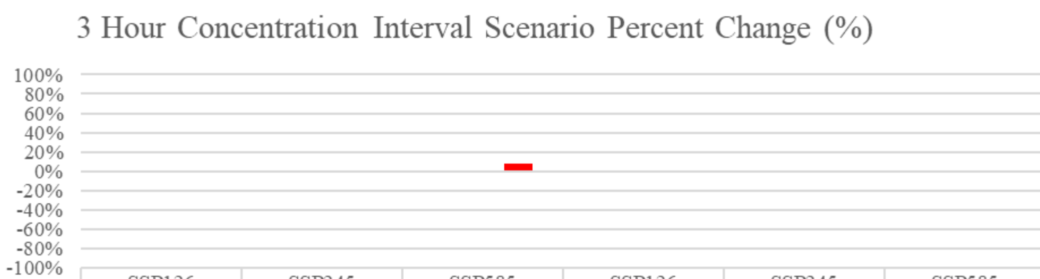
Table 8. Flood hazard area in 3 hour's concentration of rainfall for each scenario.

3 Hours Concentration Interval Flood Hazard Area (km^2)							
No	**Hazard Zones**	**Near Future**			**Far Future**		
		SSP126	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**
1	Low hazard	2640.82	2643.48	2631.20	2635.61	2636.78	2635.50
2	Medium hazard	9.35	9.36	9.29	9.27	9.37	9.30
3	High risk	39.98	39.89	40.35	40.26	40.13	40.29
4	Very high risk	160.69	158.12	170.01	165.70	164.56	165.74



	Near Future			Far Future		
	SSP126	SSP245	SSP585	SSP126	SSP245	SSP585
Medium hazard	9.35	9.36	9.29	9.27	9.37	9.30
High risk	39.98	39.89	40.35	40.26	40.13	40.29
Very high risk	160.69	158.12	170.01	165.70	164.56	165.74

Figure 11. Graph showing comparison of the area in 3 hour's concentration of rainfall for each scenario.



	Near Future			Far Future		
	SSP126	SSP245	SSP585	SSP126	SSP245	SSP585
Medium hazard	0.00%	0.03%	-0.69%	0.00%	1.02%	-0.66%
High risk	0.00%	-0.23%	1.15%	0.00%	-0.32%	0.41%
Very high risk	0.00%	-1.60%	7.52%	0.00%	-0.69%	0.72%

Figure 12. Graph showing the percent change in area in 3 hour's concentration of rainfall for each scenario.

6 Hour concentration interval

In the near future, the area prone to very high-risk flooding under the SSP-126 scenario is 144.35 km^2, the SSP-245 scenario has an area of 142.56 km^2, a decreased from the SSP-126 scenario of -1.24%, and the SSP585 scenario has an area of 151.16 km^2, an increased from the scenario in SSP-245 by 6.03%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

In the far future, the area prone to very high-risk flooding under the SSP-126 scenario is 148.81 km^2, the SSP-245 scenario has an area of 147.77 km^2, a decreased from the SSP-126 scenario of -0.70%, and the SSP585 scenario has an area of 148.99 km^2, an increased from the scenario in SSP-245 by 0.83%. According to the analysis, the scenario at SSP-585 was the worst-case scenario.

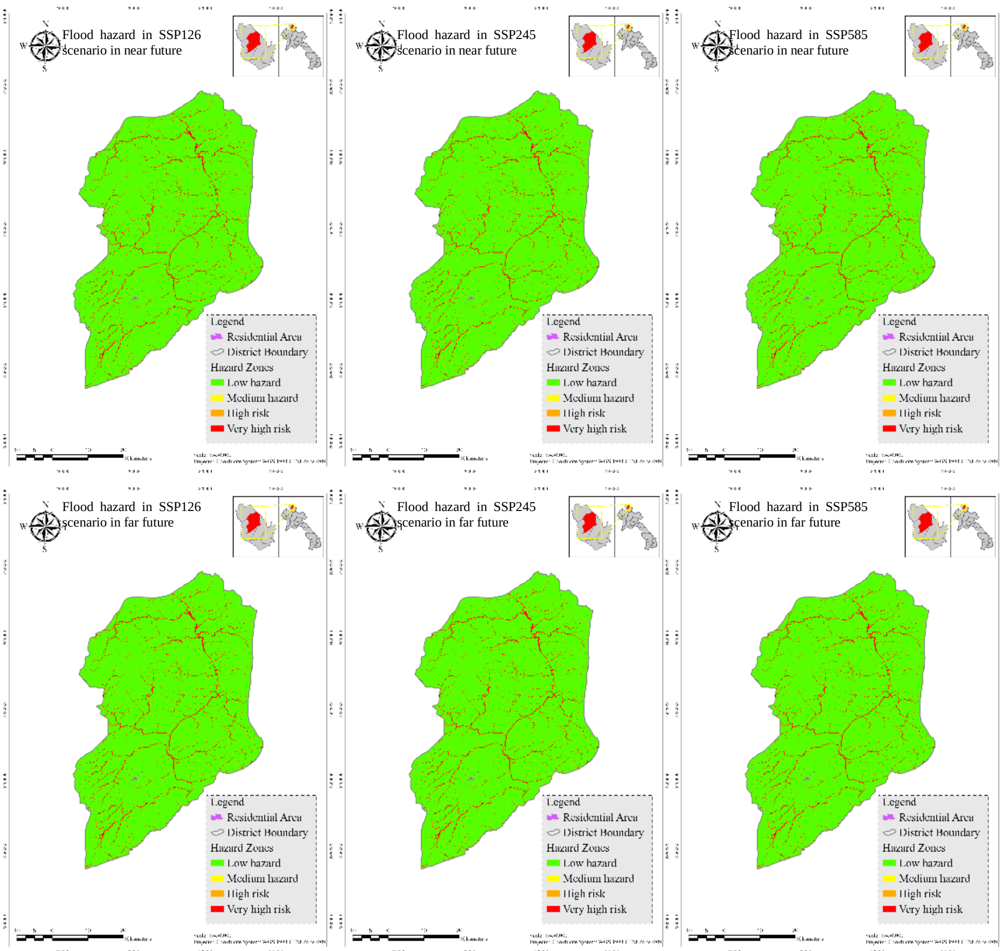


Figure 13. Flood hazard map in 6 hour's concentration of rainfall for each scenario.

Table 9. Flood hazard area in 6 hour's concentration of rainfall for each scenario.

6 Hours Concentration Interval Flood Hazard Area (km^2)							
No	**Hazard Zones**	**Near Future**			**Far Future**		
		SSP126	**SSP245**	**SSP585**	**SSP126**	**SSP245**	**SSP585**
1	Low hazard	2660.64	2662.51	2653.56	2656.20	2657.23	2659.28
2	Medium hazard	8.84	8.87	8.94	8.79	8.80	8.82
3	High risk	37.02	36.90	37.18	37.05	37.04	37.35
4	Very high risk	144.35	142.56	151.16	148.81	147.77	148.99

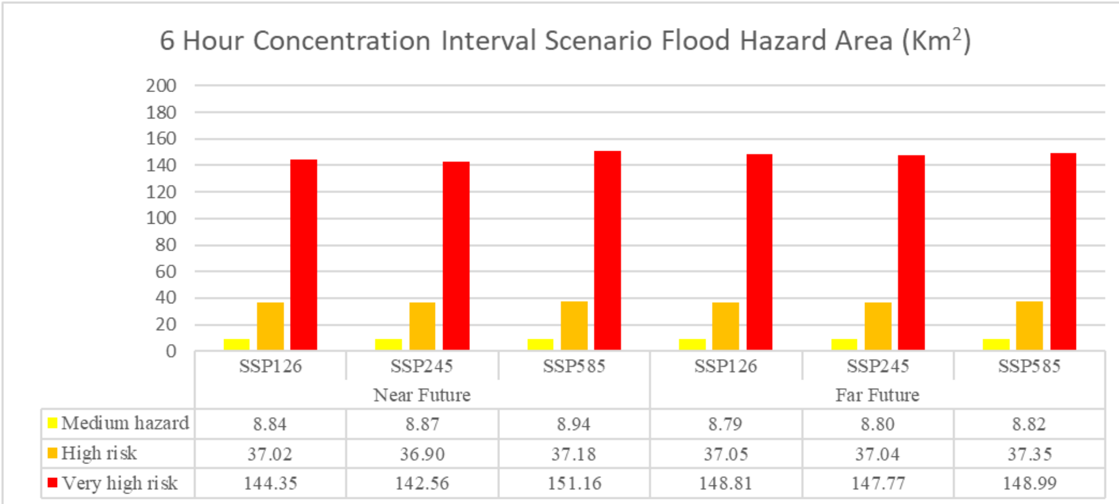


Figure 14. Graph showing comparison of the area in 6 hour's concentration of rainfall for each scenario.

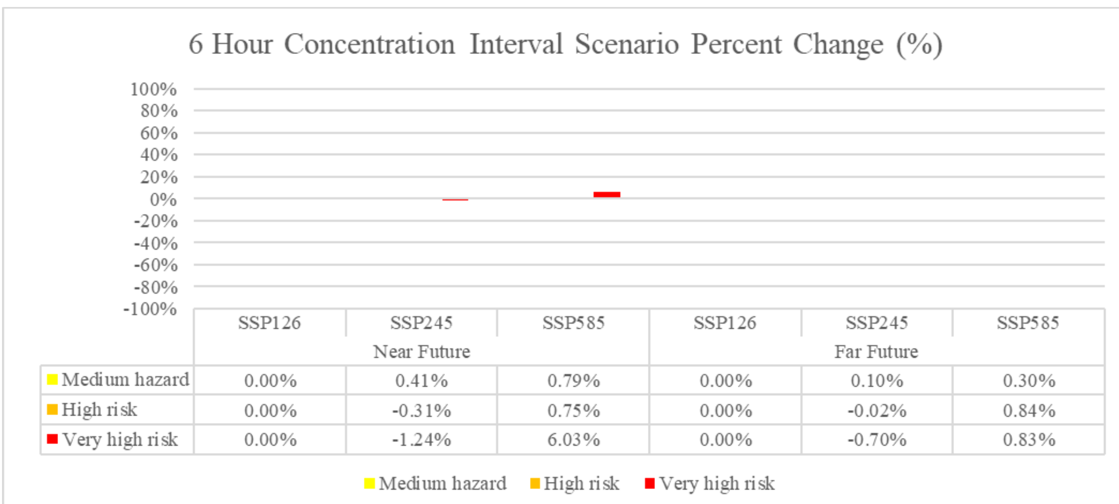


Figure 15. Graph showing the percent change in area in 6 hour's concentration of rainfall for each scenario.

Drought indices

In the near future, SPI_1 under SSP-126 experienced 16 droughts, SSP-245 experienced 19 of them, and SSP-585 experienced 19 of them. SPI_3 under SSP-126 experienced 10 droughts, and SSP-245 experienced 7, and SSP-585 appeared 17 times of them. In SPI_6 no drought was identified in any of the scenarios. Depending on how serious the scenario is, droughts happen more frequently.

(a)

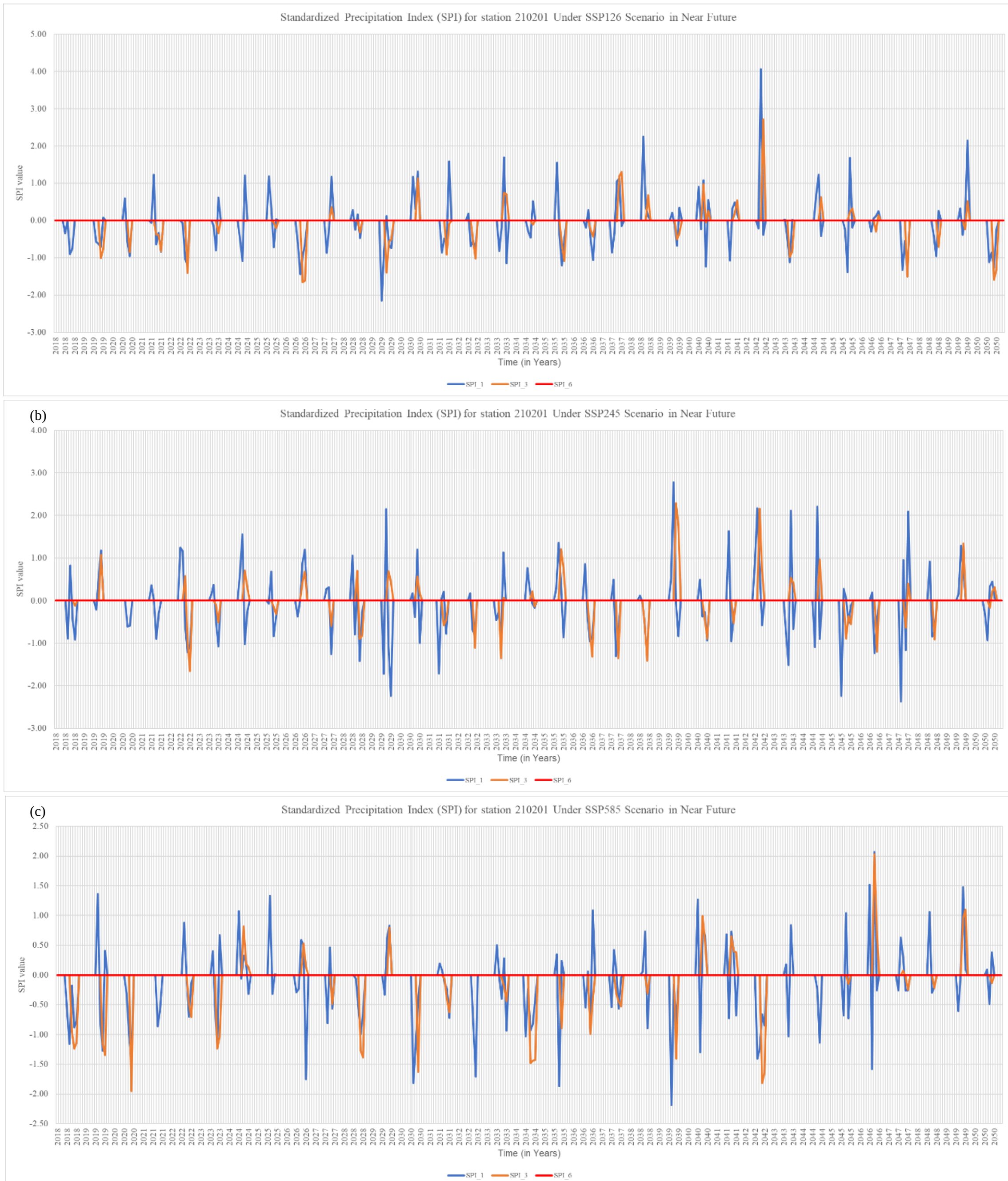


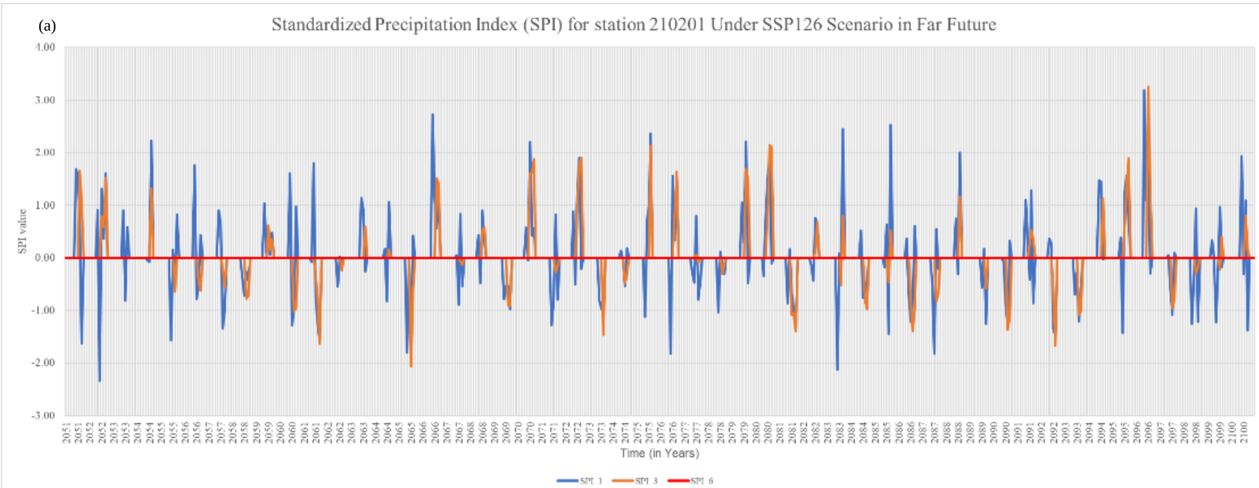
Figure 16. Comparison of SPI_1, SPI_3 and SPI_6 under (a) SSP-126, (b) SSP-245 and (c) SSP-585 in near future from year 2018-2050 at station 210201.

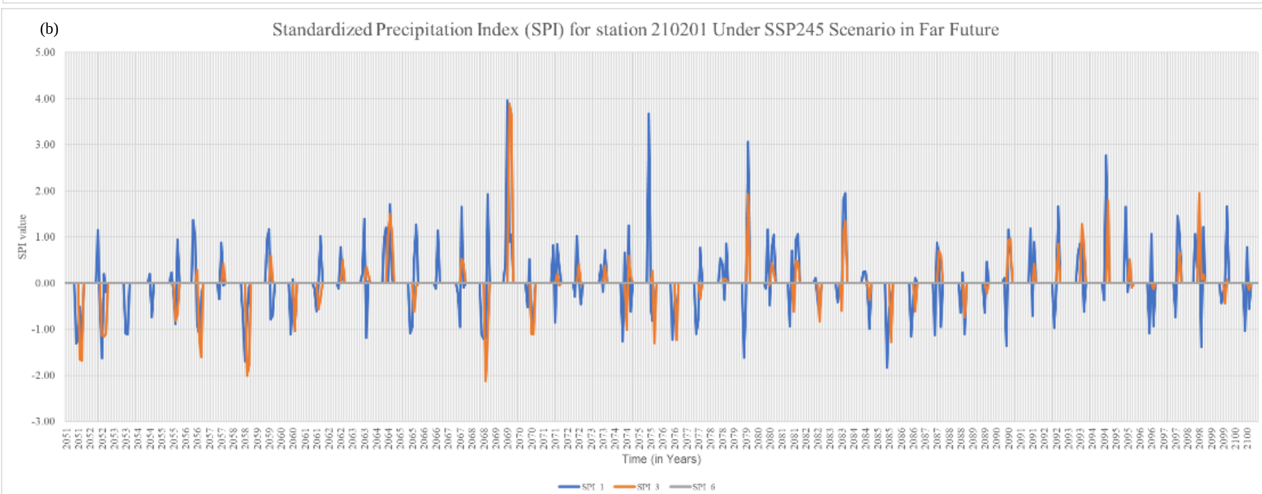
Table 10. Summary statistics of indices in near future.

Drought Index	SSP-126			SSP-245			SSP-585		
	SPI_1	SPI_3	SPI_6	SPI_1	SPI_3	SPI_6	SPI_1	SPI_3	SPI_6
Highest drought index	4.06	2.71	0.00	2.78	2.29	0.00	2.07	2.03	0.00

Lowest drought index	-2.15	-1.65	0.00	-2.37	-1.65	0.00	-2.19	-1.95	0.00
Total amont of drought (<-1, year)	16	10	0	19	7	0	19	17	0

In the far future, SPI_1 under SSP-126 experienced 32 droughts, SSP-245 experienced 29, and SSP-585 experienced 26 of them. SPI_3 under SSP-126 experienced 13 droughts, SSP-245 experienced 18, and SSP-585 appeared 7 times of them. In SPI_6 no drought was identified in any of the scenarios. In extreme scenarios, droughts occur less frequently.





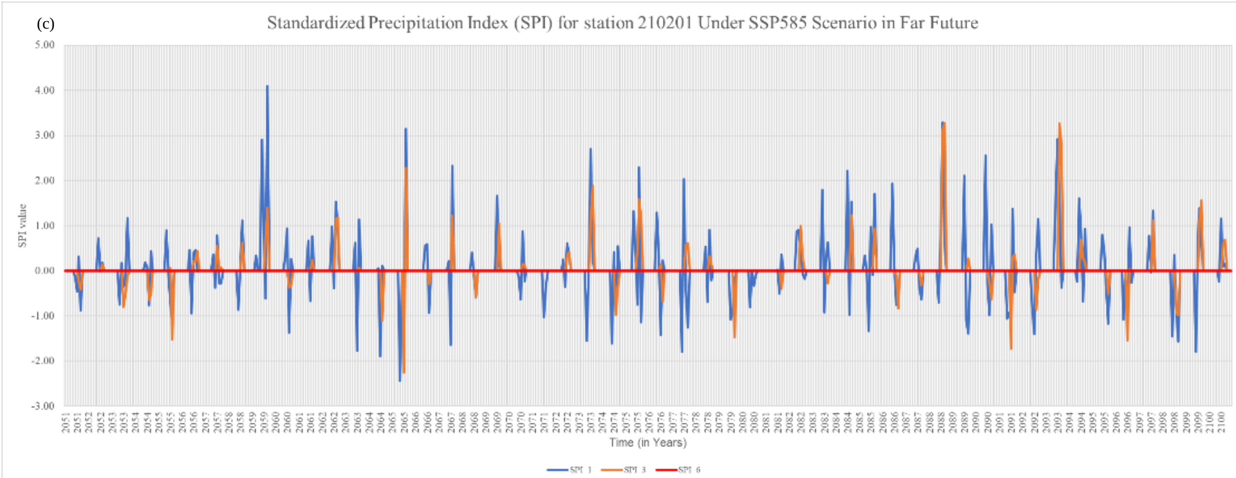


Figure 17. Comparison of SPI_1, SPI_3 and SPI_6 under (a) SSP-126, (b) SSP-245 and (c) SSP-585 in far future from year 2051-2100 at station 210201.

Table 11. Summary statistics of indices in far future.

Drought Index	**SSP-126**			**SSP-245**			**SSP-585**		
	SPI_1	**SPI_3**	**SPI_6**	**SPI_1**	**SPI_3**	**SPI_6**	**SPI_1**	**SPI_3**	**SPI_6**
Highest drought index	3.18	3.25	0.00	3.96	3.90	0.00	4.10	3.28	0.00
Lowest drought index	-2.33	-2.06	0.00	-1.83	-2.11	0.00	-2.44	-2.25	0.00
Total amount of drought (<-1, year)	32	13	0	29	18	0	26	7	0

Conclusion

Among other natural disasters, drought and flooding are undoubtedly among the more destructive yet little predicted ones. Using drought indicators for drought monitoring is frequently a crucial foundation. A better outlook of the potential risk that can befall the region is provided by drought indices and rainfall runoff models calculated from predicted rainfall. In this paper, a method is offered to compare rainfall concentration and drought indices at various time scales for further research into the respective.

Drought and flood are obviously one of the more damaging yet hardly determined natural disasters among others. Drought monitoring using drought indices often serves as an important base. Drought indices computed from forecasted rainfall gives a better outlook of potential risk that may be inflicted upon the region. In this study, a means is provided to compare among drought indices of different time scales for further study into respective drought types.

Floods are likely to become more severe as the scenario worsens. From the results of this analysis, in both periods of the 1-hour rainfall concentration under the SSP-585 scenario, there will be areas with the highest risk of flooding. In the near future, the frequency of droughts will increase as the scenario worsens, but in the far future, it will be the opposite. The frequency of droughts decreases as the scenario worsens.

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RESEARCH ARTICLE

Researching Offshore Facilities and Choosing an Appropriate Platform for Hydrate Extraction in the Bay of Bengal

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Abstract
Offshore buildings are used in various locations and sea depths for several reasons. Different equipment, platforms, and design techniques are needed depending on water depth, climatic conditions, structural arrangement, and new concepts. Offshore constructions usually generate and transport oil, gas, and other commodities. Bangladesh has yet to use the Bay of Bengal's hydrocarbon potential for oil and gas. Bangladesh lags behind India and Myanmar in maritime oil and gas discovery. In 50 years, Bangladesh's sea barriers have yielded no benefits. Bangladesh's economy is hindered by its high crude oil imports. Focus on offshore petroleum exploration to locate "black gold" now. Therefore, an offshore structure is needed. This thesis paper covers the fundamentals of all offshore systems, broadens the research, and recommends appropriate platforms for various sea-water depths, which those platforms are meant to be built for hydrates predicted in the Bay of Bengal. The paper uses the Bay of Bengal sedimentation and estimated water depth to choose offshore constructions. The country's maritime boundaries have 26 oil and gas blocks. There are 11 in shallow water and 15 in deep sea. According to statistics, the blocks are on the continental shelf and deep-water region. Five zones make up the Bay of Bengal continental shelf. They are shores A-B, B-C, C-D, D-E, and E-F after region F continental slope continues till the deep sea area. The continental slope zone C-D has 64-106 m water depth. Therefore, the Bay of Bengal continental shelf is suitable for all permanent offshore buildings except this zone. Only concrete gravity platforms fit this zone. We need the technology to search for oil and gas in water. It takes a lot of work to get foreign companies to work together. Thus, skilled people should work on it and encourage government or private businesses to develop oil and gas production technology.

Keywords: Offshore Structures; Hydrocarbon; Bay of Bengal; Continental Shelf; Sediment

Introduction

Offshore describes a location on water that is far from land. However, offshore construction entails erecting buildings and other infrastructure out at sea. Offshore structures are typically constructed and pre-commissioned on the ground. Offshore structures exposed to waves, seismic activity, wind, or a mix of these stressors exhibit non-linear, abrupt behavior. The ocean floor's topography is analyzed for petroleum reserves after seismic studies have been conducted. When the probability of finding hydrocarbons is high, the surveyor is prompted to dig deeper, and the quantity of hydrocarbon potential yields figures for the most cost-effective offshore building in the area. Oil and gas are being explored all over the planet. Onshore exploration refers to work done on land, while offshore research occurs in water. There is also a third zone, but it has a minor trade effect. Transition Zone Exploration is another name for this, though Shallow Water Exploration is more common. This includes areas with shallow water, such as coastal areas, waterway channels, and swamps. Exploration methods in such regions are often complex.

Offshore building projects have their own technical and monetary quirks. Offshore building projects rely heavily on the profits made from oil and gas extraction, which are directly linked to international finance and indirectly affected by oil price fluctuations. For instance, numerous offshore construction projects were initiated in 2008 as a direct consequence of the increase in global energy costs that year (Atreya et al., 2013)

Soon after Bangladesh became an independent country in 1971, oil was taken out of the ground for the third time (1971–1990). Six multinational companies, including ARCO, Ashland, and Union Oil Co., sank seven wells in the Bay of Bengal between 1974 and 1978 to investigate distant areas under Production Sharing Contracts with Petrobangla (the state oil company). Thus, the distant Kutubdia gasfield was discovered. One thousand nine hundred eighty all foreign energy companies had left Bangladesh, leaving only Petrobangla. A petroleum reservoir's porosity and permeability are crucial physical qualities when storing and transporting fluids. Both characteristics are essential when defining a reserve. Particle size and form, pore size, grain sorting, cementation, compression, packing fracture, and solution are significant in determining reservoir-scale porosity and permeability. However, aside from the work of a few undisclosed oil and gas companies in the Bengal Basin, no efforts have been made to quantitatively quantify core and log petrophysical characteristics and their potential governing variables (Ismail & Shamsuddin, 1991).

Bangladesh has relatively small hydrocarbon and lignite deposits, but its natural gas supplies could be huge. Most natural gas and petroleum oil come from Sylhet Division in the country's northeast, followed by Chittagong Division, Dhaka Division, and Barisal Division. Most people think that Bangladeshi natural gas is one of the cleanest in the world because it has a high methane content (95–99%) and almost no nitrogen content. Of the total 25,602 km2 that was in question, Bangladesh got 19,467 square kilometers (km) of territory in the sea from The Hague's Arbitral Tribunal, which presided over the maritime border dispute between Bangladesh and India in the Bay of Bengal. Therefore, the marine sector in Bangladesh holds excellent promise. The Bay of Bengal is home to numerous oceanic islands that may be highly mineral-rich. Furthermore, UNB reports that Bangladesh has discovered massive potential natural gas hydrate deposits in its Exclusive Zone, with estimates ranging from 0.11 to 0.73 TCF. It is equivalent to 17–103 trillion cubic feet (TCF) of natural gas (Shahjahan et al., 2002).

Bangladesh is rich in natural resources and spans an area of 147,610 square kilometers, stretching from north to south for 820 kilometers and from east to west for 600 kilometers. Regarding geography, the Bengal Basin can be found in an area characterized by exceptionally high levels of geological activity. A great number of dynamic geological features can be found within and all around the Bengal Basin. The region of the Indian Ocean, located to the northeast, is defined by the estuary of Bengal, the largest estuary in the globe. It is a triangular shape and is bordered on three sides by other countries: to the north by Bangladesh, to the east by Myanmar and the Andaman and Nicobar Islands, and to the west by India and Sri Lanka. The Bay of Bengal encompasses a total area of 2,172,000 km2 of land and water. To use a metaphor, the country of Bangladesh sits at the very tip of the Bay of Bengal. The length of the nation's exclusive economic zone is 370 kilometers (200 nautical miles), while the size of its territorial waterways is 12 nautical miles (22 kilometers). The land is reportedly subdivided into 26 separate sections, as stated by Petrobangla. The PSC district plan is presented in the following image. There are 11 sections from the coastal sea and 15 blocks from the deep sea. On the chart, far offshore is represented by a dark blue color, while shallow offshore is shown by a lighter blue color (Shahjahan et al., 2002).

Since the industrial revolution, energy demand has grown while supply has not. Bangladesh's power sector relies largely on fossil fuels since natural gas and coal are its main energy sources. Diesel, coal, heavy oil, and biofuels comprise the rest of Bangladesh's power generation. Bangladesh's energy field includes power, fuel products, natural gas, coal, biogas, and sun. Exploiting its abundant green energy sources may solve Bangladesh's power issue. The problem should be addressed by massively using ocean waves and the Bay of Bengal. Offshore buildings and energy use are the most effective way to use Bay of Bengal resources.

The following research and investigation objectives were set in light of the preceding discussion:

- Explore about offshore structures in detail in preparation for their use in the near future;
- Examining the potentiality of Bay of Bengal blocks for offshore constructions;
- Prediction of primary selection of offshore structures for those hydrocarbon potential area.

Literature Review

Detailed Study on Offshore Structures

Maritime and offshore structures must withstand harsh sea conditions for their plan spans. (50 to 75 years for ports and 25 years or more for offshore hydrocarbon platforms). Peak loads from storm gusts and waves wear loads from waves over the platform's lifespan and platform motion are essential to design aspects. Offshore buildings are built miles from shorelines in lakes, gulfs, and the open sea. These structures are made of mild to high-strength steel. The world's tallest artificial buildings are offshore towers. This chapter covers offshore building history, kinds, and loads that must be computed for design, plans and specs, production, installation, and environmental considerations (Ismail & Shamsuddin, 1991).

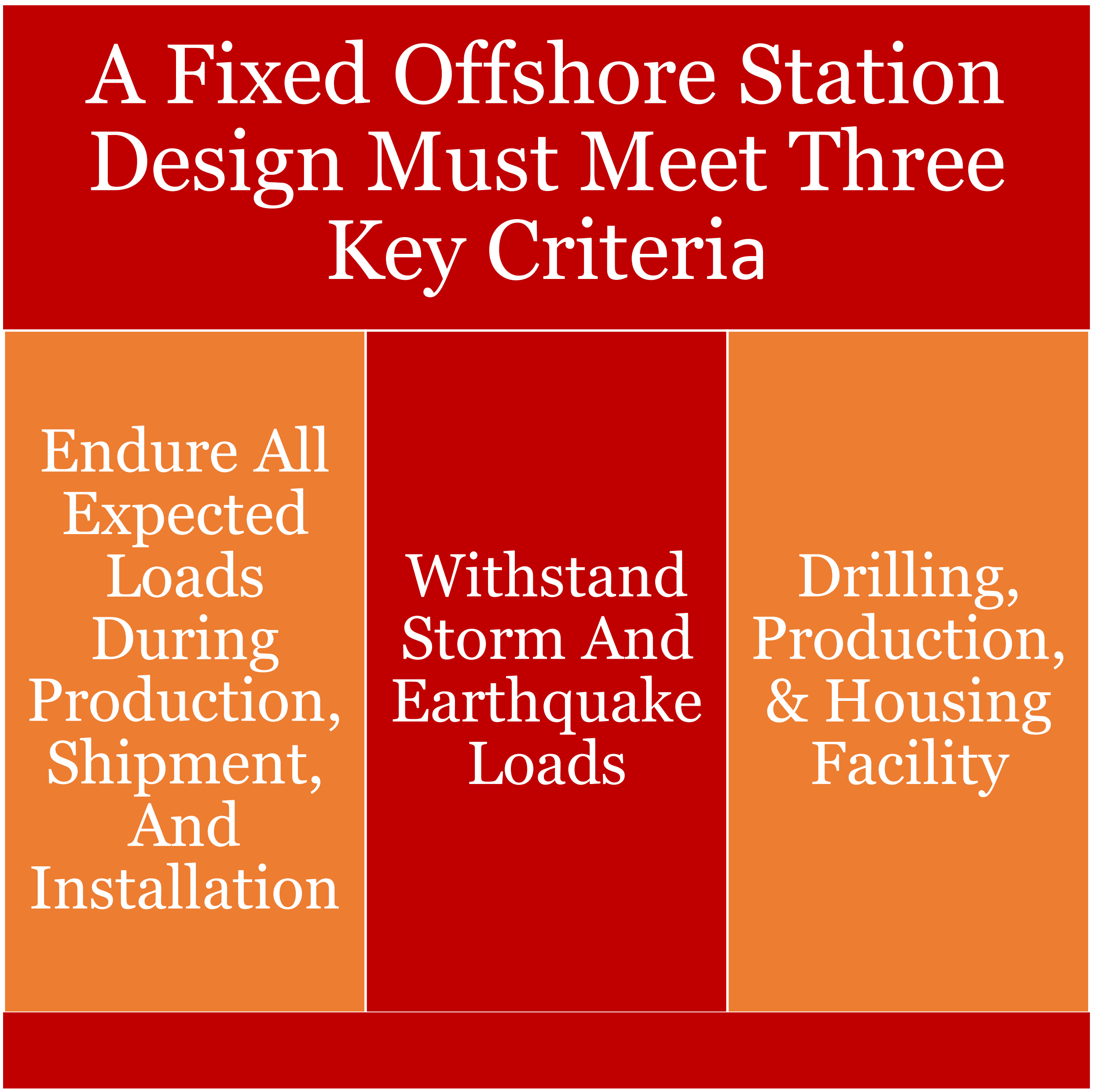

Figure 1. Three key criteria for offshore station design (Bhattacharya et al., 2006).

From 1909 to 1910, Louisiana dug wells. Timber derricks were raised on hastily built timber supports on woodpiles. Two main types of fixed platforms have evolved in the past 40 years: the concrete gravity type, built in the North Sea, and the steel template type, built in the Gulf of Mexico (GoM). Due to the need to dig deep water wells and build deepwater gas projects, the tension-leg platform was introduced as a third type. In 1976, Exxon built a 259-meter-deep platform in Santa Barbara. (850 ft.). The most widely used form of energy and liquid fuels is crude oil, and its use is likely to persist for decades (Dawood et al., 2013).

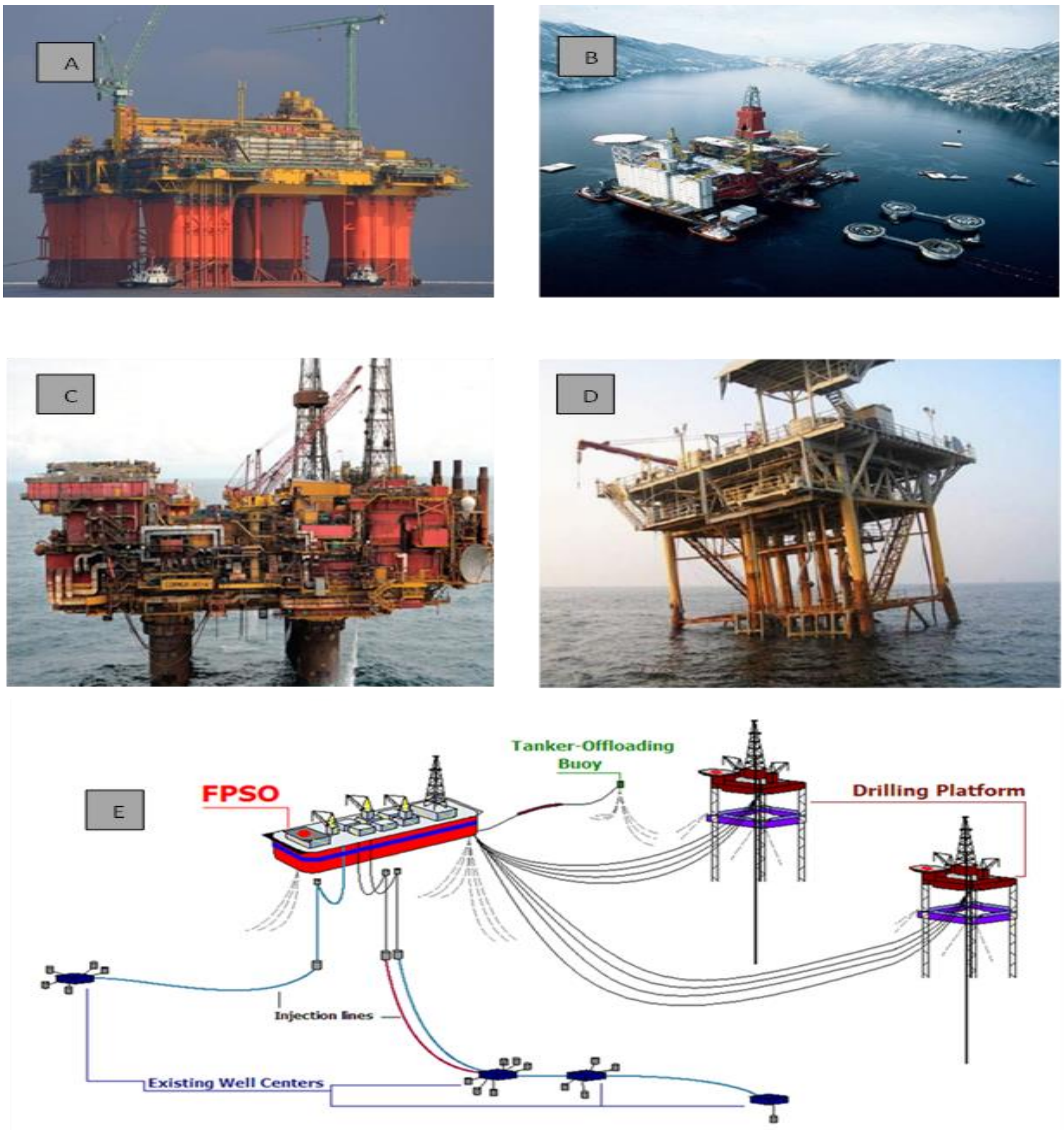

Figure 2. Offshore Structures. (A) Floating Production System; (B) Concrete Gravity Platform; (C) Complaint Tower; (D) Fixed Steel Template Structure; (E) Process of Floating, Production, Storage and Offloading (Dewangan et al., 2010).

About 1950, BP conducted similar studies in Abu Dhabi. Persian Gulf The activity has grown steadily in water less than 30 meters (100 feet). In the 1960s, GoM hurricanes damaged the station, forcing a redesign. Hurricane Hilda in 1964 destroyed 13 platforms with 13-meter waves and 89-meter-per-second winds. The following year, typhoon Betsy, a 100-year storm, injured several stations and destroyed three. Designers began planning for 100-year storm repeat periods instead of 25 and 50 years.

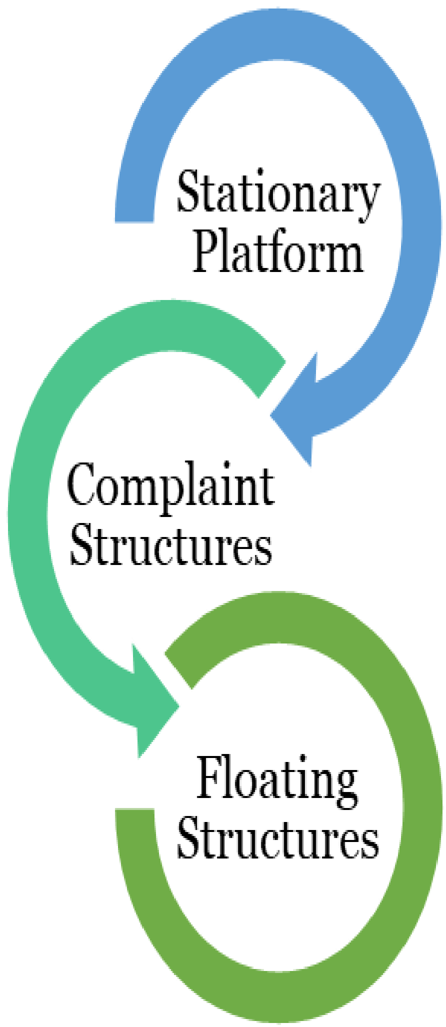

Figure 3. Types of Offshore Structures (Bhattacharya et al., 2006)

The region of the Indian Ocean, located to the northeast, is defined by the estuary of Bengal, the largest estuary in the globe. It is a triangular shape and is bordered on three sides by other countries: to the north by Bangladesh, to the east by Myanmar and the Andaman and Nicobar Islands, and to the west by India and Sri Lanka. The Bay of Bengal encompasses a total area of 2,172,000 km2 of land and water. To use a metaphor, the country of Bangladesh sits at the very tip of the Bay of Bengal (Maurin & Rangin, 2009). The nation's exclusive economic zone is 370 kilometers (200 nautical miles), while its territorial waterways are 12 nautical miles (22 kilometers). The land is reportedly subdivided into 26 separate sections, as stated by Petrobangla. The PSC district plan is presented in the following image. There are 11 parts from the coastal sea and 15 blocks from the deep sea. On the chart, far offshore is represented by a dark blue color, while shallow offshore is shown by a lighter blue color (Solomon, 2020).

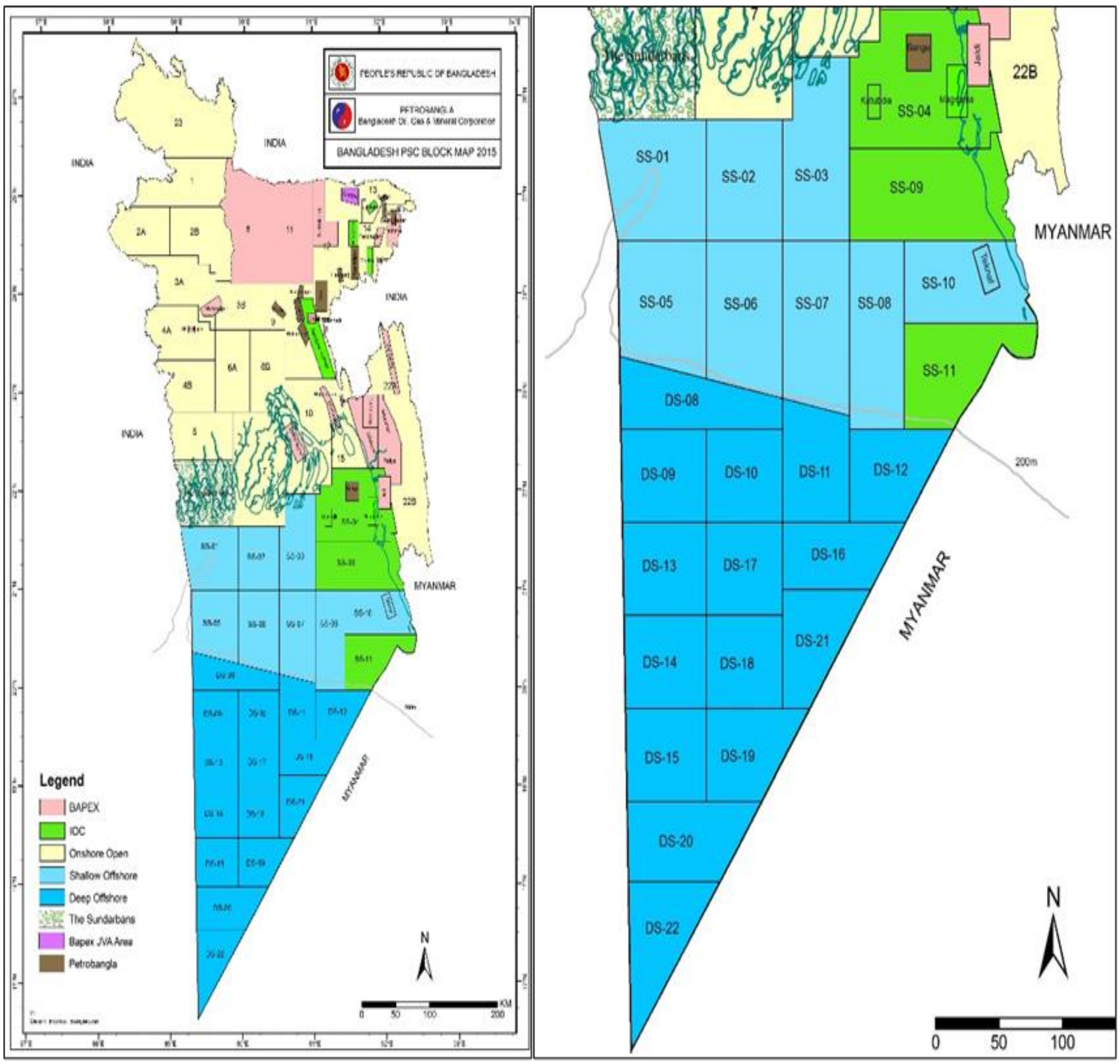

Figure 4. Shallow Offshore and Deep Offshore Blocks. Working Blocks (Shahjahan, et al., 2002).

Offshore Section Resources

Bangladesh produces the 15th most natural gas in Asia. Bangladesh's northeast, east, southeast, and south corridors yielded natural gas. Sangu is Bangladesh's only offshore gas field. Sylhet's Haripur contains natural oil, but the region's only oil well produces too little. Bangladesh is behind other nations in oil and gas research because the energy sector has yet to help the economy as much as expected. Bangladesh's oil and gas assets are hard to estimate due to a lack of exploration data and ocean digging. This paper summarises the Bay of Bengal and Bangladesh marine petroleum scenario. The Bengal Basin provides gas and a few liquid fuels (mainly condensates and light oil). In the Bengal Basin, Oligo-Miocene sediments are source rocks, and Miocene-Pliocene sediments are storage rocks. Most studies of the Bengal basin's parent rocks have focused on middle Miocene strata dug from depths greater than 4 kilometers (Ismail et al., 2014). The Surma Group unconformably overlies the Paleogene turbidites, and the submerged fan complex appears to have persisted into the upper deep water. Deep-marine facies connections of abundant petroleum deposits have gotten the least attention (Dasgupta, 2004).

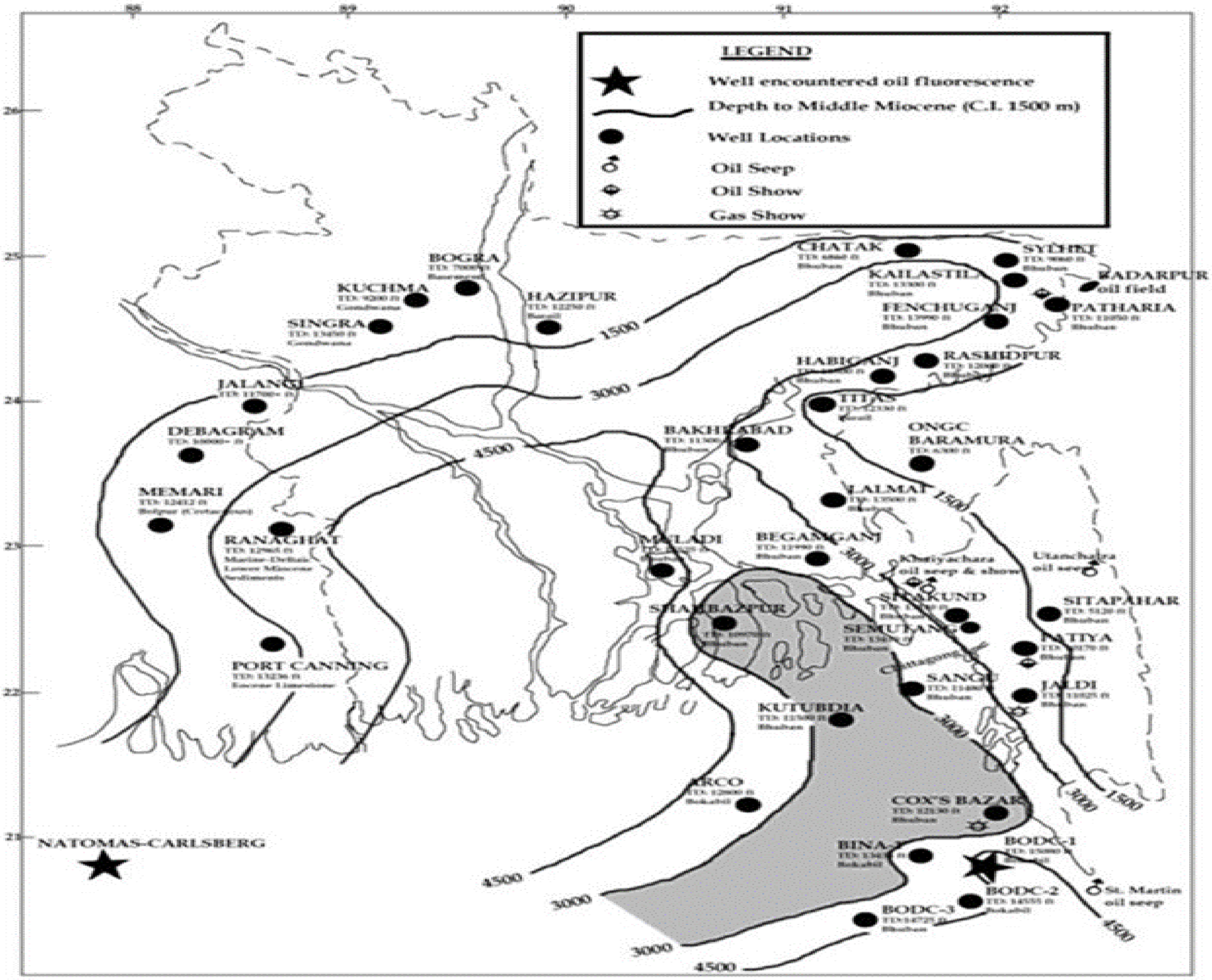

Figure 5. Hatia depression and the ocean area are depicted on a contour depth map, the mid-Miocene strata that lie within it serving as a petroleum reserve (Dasgupta, 2004).

The Bhuban Formation formed the offshore Bengal Basin Hatia Petroleum System. Beyond the Surma basin to the south and southeast, oil and condensate are isotopically denser (-24.5 to -26.6%) with negative canonical features, indicating marine or marine-influenced source rocks from type-II or type-II/III kerogen. The oil output window is between 5400 m and 10000 m because sands with low vitrinite absorption bury quickly. Methane carbon isotope rates indicate that Miocene and Pliocene pools contained old parent rock (Roybarman, 1987). A study of the source rock potential of chosen cores from the Muladi-1 well in Bangladesh found that extractable organic material linked to carbon content rises with depth in shale samples, suggesting age and source oil. Oil leaks at Hararganj, Sitakund, Utan Chatra, and the Patharia indicate that mature source rocks produced liquid petroleum during the oil production window. Except for the lower Miocene gas-prone source rocks, the horizons of the Oligocene, upper Eocene, and Paleocene show fair to excellent oil source potential, with an oil window maturity zone between 5000 m and 8000 m in the deeper basin. Geochemical and source rock palynological data from West Bengal, India, suggests that the mature source rocks of the Paleogene-Early Neogene series may be located at the Eocene slope break (Hasan & Qasim, 2017). Wet gas is more common in cores from the MND-2 well in the offshore Mahanadi basin below 3300 meters, while mature source rocks for oil are at 2500 meters (Basal Miocene). Due to its continuous fracturing and delta build-up, the Jenum Formation of the Oligocene Barail Group, the main source rock in Assam and the Surma basin is widely regarded as the offshore Bengal Basin source rock. Geologists believe Bengal Basin deposits are source rock and top rock. These sands aided hydrocarbon capture.

The ocean area has folded and inverted crustal segments. Find extremely high buildings (Saiful et al., 2011). Younger bending and reversal between paleode and neode formation fronts are usually minor and straightforward. Inversion zones may acquire tiny, hidden bends. Controlled faulting and structural closures are likely. Hydrocarbon migrates vertically through cracks and laterally up-dip over pale slopes, making the offshore Bengal Basin ideal for hydrocarbon capture at 4-6 km. Channels filled with mud and sand, channel sands, incised valleys where heavy channeling happened, and pro-delta clays that move up-dip to delta-front sand wedges are ideal petroleum traps (Greaves et al., 2017).

Table 1. Offshore Suitability Regarding Water Depth of the 26 blocks of Bay of Bengal (Ismail & Shamsuddin, 1991).

Blocks	Water depth	Area	Suitable platform
SS-01 to SS-08 SS-11	Up to approximate 200 m	Each have exploration area 4500 and 7700 sq. km.	Both concrete gravity and steel template platform
SS- 09, SS- 10	Up to approximate 200 m	Each have exploration area 4500 and 7700 sq. km.	Concrete Gravity
DS- 12, DS- 16, DS-21	Between 2000 to 2500 meters	Each have exploration area between 3200 and 3500 sq. km.	Larger TLP, SPAR platform, FPSO, Semi-submersible platform
DS- 08 to DS- 18	Between 2000 to 2500 meters	Not found	Larger TLP, SPAR platform, FPSO, Semi-submersible platform
DS-19	Between 2000 to 2500 meters	Approximate 11170 sq. km.	Larger TLP, SPAR platform, FPSO, Semi-submersible platform
DS-20	Between 2000 to 2500 meters	Approximate 12153 sq. km.	Larger TLP, SPAR platform, FPSO, Semi-submersible platform
DS-22	Between 2000 to 2500 meters	Approximate 12454 sq. km.	Larger TLP, SPAR platform, FPSO, Semi-submersible platform

The offshore Bengal Basin's Hatia Petroleum System began in the Bhuban Formation. Beyond the Surma basin to the south and southeast, oil and condensate are isotopically denser (-24.5 to -26.6%) with negative canonical features, indicating marine or marine-influenced source rocks made from type-II or type-II/III kerogen. Since layers with low vitrinite absorption bury quickly, the oil output window is expanded between 5400 m and 10000 m (Shahjahan et al., 2002). The parent rock in Miocene and Pliocene pools was old based on methane carbon isotope ratios. According to a study of the source rock potential of chosen cores from Bangladesh's Muladi-1 well, extractable organic material linked to carbon content rises with depth in shale samples, suggesting age and source oil [9]. The Patharia well's oil show and leaks at Hararganj, Sitakund, and Utan Chatra suggest that mature source rocks produced liquid petroleum during the oil production window. Except for the lower Miocene gas-prone source rocks, the horizons of the Oligocene, upper Eocene, and Paleocene show fair to excellent oil source potential, with an oil window maturity zone between 5000 m and 8000 m in the deeper basin. Geochemical and source rock palynological data from West Bengal, India, suggests that the mature source rocks of the Paleogene-Early Neogene series may be located on the Eocene slope break (Imam & Hussain, 2002). According to studies of cores retrieved from the MND-2 well in the offshore Mahanadi basin, wet gas is more common in samples below 3300 meters, while mature source rocks for oil are at 2500 meters (Basal Miocene). The Jenum Formation of the Oligocene Barail Group, the primary source rock in Assam and the Surma Basin is widely regarded as the source rock in the offshore Bengal Basin due to its continuous fracturing and delta build-up. According to geologists, the Bengal Basin may contain source rock and cap rock deposits. These layers may have helped trap hydrocarbons. In the distant area, crustal segments show unique bending and inversion patterns. High-rise buildings may be found. Younger bending and reversal between the paleode formation and neode formation fronts is simple and tiny (Islam, 2010). Inversion zones can produce tiny, hidden bends. Structural openings with managed faulting are likely. The offshore Bengal Basin has favourable hydrocarbon capture at depths of 4-6 km because hydrocarbon migrates vertically via cracks and laterally up-dip over paleoslopes. Channels, channel sands, cut valleys, and pro-delta clays that move up-dip to delta-front sand wedges are ideal geological traps for hydrocarbons (Lafond, 1957).

Methodology

This is an observational study that required a lot of time spent behind a computer and in a library. Review study focused on whether or not floating structures in the Bay of Bengal would be safe to inhabit. Literatures pertinent to marine buildings that need to be reviewed include printed materials (books, journals, and periodicals), internet journal articles, and symposium papers. (Google Scholar, web of knowledge).

Results and discussions

The term "petroleum resources" refers to the estimated quantities of hydrocarbons on and below the planet's surface. The potential for a resource to be recovered and sold is estimated in both resource assessments and resource evaluations, while the latter focuses mainly on the latter. Bangladesh's considerable hydrocarbon potential has been the subject of several resource evaluations and publications, either independently by different government agencies or in partnership with Petrobangla. Bangladesh is a good location for numerous active petroleum systems since its potential source rocks span from the Cretaceous to the Miocene, which is old enough to enable hydrocarbon accumulation in any competent conventional trap. This article shows the accessible resources and a good platform for extracting hydrocarbons. However, there needs to be more knowledge to make educated judgments now. Both coastal and deep sea areas are included in the 26 oceanic regions. Building choices can only be made with a degree of certainty once we have a better understanding of the sedimentary composition of the area. The offshore basin was sedimented twice: first in the Triassic, when the Sibumasu terrane moved from Gondwanaland and produced the West Burma block, and again in the early Tertiary, when India collided with Eurasia, constructing the Himalaya (Dyanati & HuangQ, 2014).

The continental shelf at the head of the Bay of Bengal is as much as 100 miles wide but narrows to the south. The features of the continental shelf in this region are as follows:

- A width of approximately 25 miles.
- An average slope of 0 degrees and 15 minutes.

- A depth at the outer edge of around 100 fathoms.

A unique feature is that the shelf can be divided into five zones. Each has its own set of slopes and sediments. A sixth zone comprises the upper part of the continental slope. Each zone runs nearly parallel with the shore. The average widths, slopes, and depths of those zones are given below:

Table 2. Continental Shelf Zone

Zone	Width(mi)	Slope (Degrees)	Depth(fms)	Depth of zone
Shore A-B	2	0 degree 26 minute	0-15	0m to 27m
B-C	11	0 degree 4 minute	15-35	27m to 64m
C-D	6	0 degree 11 minute	35-58	64m to 106m
D-E	2	0 degree 35 minute	58-70	106m to 128m
E-F	2	1 degree 9 minute	70-112	128m to 205m

There is a lot of Globigerina ooze in the sediments of the deep Bay of Bengal basin, which is one of the things that sets them apart. The continental slope yields dark gray samples with a bluish tint and a pliable, soft texture. Several blocks in the DS series are located in an area with deep water: DS-12, DS-16, DS-21, DS-19, DS-20, and DS-22. Hydrocarbon source rocks are characterized by a high maturity level within the oil generation window for deeper sediments, consistent with a marine environment of deposition. Sites in deep water are typically situated in regions with thick sediment deposits on the continental slopes that slope gently into the abyssal plains. In these regions, the average slope of the seafloor is relatively shallow (less than 4 degrees).

Using buoy-measured data from February 2013 to December 2015 off Gopalpur at a depth of 15 meters, this article describes the spectral wave characteristics of the nearshore waters of the northwest Bay of Bengal. The southwest monsoon is associated with increased wave heights and more extended wave periods, as indicated by the seasonal mean significant wave height and mean wave period. A year's worth of waves between 138 degrees and 228 degrees accounts for 74% of the variation in sea level, with those between 48 degrees and 138 degrees accounting for 16%. The monthly average wave parameters show substantial interannual variability due to the occurrence of tropical cyclones. On October 12, 2013, a significant peak wave height of 6.7 meters was recorded due to the effects of Tropical Storm Phailin. On October 12, 2014, a significant peak wave height of 5.84 meters was recorded due to the effects of Tropical Storm Hudhud, whose track was 250 kilometers southwest of the study location. The analysis showed that a single tropical cyclone affected the annual maximum significant wave height, while the annual average value was nearly identical (1 m) in both 2014 and 2015. Western Bay of Bengal waves are affected by cyclones, swells from the Southern Ocean, and the southwest and northeast monsoons (Maurin & Rangin, 2009).

Table 3. Platforms According to Water Depth

Platforms	Required water depth
Concrete Gravity Platform	within 200 m and best from 100 m to 150 m, can be suited up to 350 m
steel template structure	Up to 500 m
Complaint Structures	Normally 300 m to 600 m
Larger TLP	Successfully has reached 1250 m
Spar Platform	Presently used up to 1000 m though technology can extend up to 2500 m (Deep water platform)
FPSO	Up to 2600 m
Semi-submersible	1800 m

Conclusion

Hydration study has resurfaced among experts worldwide due to several reasons. It could become the next generation's pure energy norm. Hydrates are abundant worldwide. The upstream offshore oil and gas value chain includes drilling rigs, research and support ships, platform building, production, and extraction. Downstream work includes refining and selling goods. Our energy supply, primarily natural gas and a potential new oil sector at sea, rests mainly on fossil fuels, which can be dug and handled. Bangladesh still needs to assess its marine petroleum potential. Bangladesh has 26 TCF of gas, but only 1 TCF is offshore. Up to 2014, 19 exploratory wells were dug in the Bay of Bengal, but only two gas finds—the Sangu and the Kutubdia—had minimal amounts. Sangu's 0.8

TCF stocks are gone, but Kutubdia's 0.04 TCF are not. The Magnama (3.5 Tcf) and Hatia (1.0 Tcf) have been dug but have not yielded marketable petroleum. Bangladeshi areas near Myanmar's gas deposits may have similar natural traits and gas or oil prospects. Thus, subsea structures for harvesting deposits and developing current structures are essential. Water depth and deck tools determine which level is best. Fixed platforms of steel template and concrete gravity fit Blocks SS-01, SS-02, SS-03, SS-04, SS-05, SS-06, SS-07, SS-08, and SS-11, which have ocean depths up to 200 m and layers without rock zones. Since SS-09 and SS-10 are in a rock zone, concrete gravity is best. The deep-sea rocks' geological knowledge is limited to their 2000–2500 m ocean level. We cannot specify a platform for those pieces. We can only recommend deep-water platforms like bigger TLPs, SPAR, FPSOs, and semi-submersible platforms.

A well-planned approach for finding oil and gas areas and deposits is needed to perform a multi-line scan in the Bay using cutting-edge technology. Whoever drills last is likely to pull not only their fair share of gas and hydrocarbon reserves but also those from across the boundary, so any delay in exploration could negate the opportunity to harness hydrocarbon resources, especially those (if any) located on either side of the maritime boundary (India and Myanmar). Extensive digging and research are needed to increase gas output. Petroleum extraction will require public-private cooperation to share data, information, tracking, best practices, assessment methods, and results. In order to predict resources for future use, the government should build a hydrate-stable map of the nation in the Bay of Bengal area.

• Little research was conducted on the distant regions, so scarce information was available.
• Since underwater building is so novel, there are few tools to draw from.
• The marine islands of Bangladesh have never been surveyed. This means that no information regarding the area's bathymetric shape exists.
• Tides, currents, ocean temperature, and other aspects of that marine region were poorly understood.

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RESEARCH ARTICLE

Comparative Analysis of Sustainable Finance Initiatives in Asia and Africa: A Path towards Global Sustainability

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Abstract
This article conducts a meticulous comparative analysis of sustainable finance initiatives in Asia and Africa, exploring their impact, efficacy, impediments, and prospects towards global sustainability. The study seeks to identify similarities and differences between the two regions, uncovering their strengths and weaknesses to inform prudent strategies and best practices for advancing sustainable development worldwide. Emphasizing the significance of sustainable finance as a catalyst for ecologically sound and socially responsible investments, the research examines regulatory frameworks, financial innovation, and successful case studies in both regions. Asia's accomplishments are exemplified by mechanisms like green bonds, impact investment funds, and sustainability-linked loans, bolstered by collaborative efforts, capacity building, and data transparency. Similarly, Africa's potential shines through robust regulations, financial innovation, and capacity-building initiatives that attract sustainable investments and foster transformative development. The article concludes with recommendations to enhance global sustainable finance, emphasizing clear regulatory frameworks, integrating sustainability in financial institutions, and investing in comprehensive capacity building programs.

Keywords: Sustainable finance; Comparative analysis; Asia; Africa; global sustainability and Capacity building

Introduction

The global community recognizes the urgent need for sustainable development practices to tackle environmental and social challenges. Sustainable finance has emerged as a crucial tool in mobilizing financial resources for eco-friendly and socially responsible projects. By integrating sustainability into investment decisions, it aims to drive positive economic, social, and environmental outcomes (UNEP, 2020; World Bank, 2021).

Asia and Africa, characterized by diverse economies and developmental challenges, have witnessed significant traction in sustainable finance initiatives. These continents experience rapid economic growth, industrialization, and urbanization, leading to environmental risks and social inequalities (ADB, 2019; AfDB, 2022). Governments, financial institutions, and businesses in Asia have introduced policies and frameworks to incentivize sustainable investments (ADB, 2020; GRI, 2021). Initiatives like green bonds, sustainable lending, and impact investing have gained momentum, directing funds towards climate change mitigation and sustainable infrastructure (UNESCAP, 2021; IFC, 2022).

In Africa, sustainable finance initiatives address socio-economic disparities and environmental vulnerabilities (AfDB, 2021). Governments, international organizations, and financial institutions recognize sustainable finance's role in unlocking the continent's potential and achieving sustainable development goals (UNECA, 2020; IUCN, 2021). Activities include microfinance for rural communities, innovative climate adaptation financing, and partnerships for sustainable agriculture and natural resource management (UNDP, 2020; GCF, 2022).

Understanding the context of sustainable finance initiatives in Asia and Africa is crucial to comprehend motivations, challenges, and opportunities (ESCAP, 2022; UNEP FI, 2022). Factors like governance, regulations, access to capital, technology, and culture influence outcomes (World Bank, 2020; ILO, 2021). A comparative analysis offers valuable insights, identifying successful models and sharing best practices to foster global sustainability (UNEP FI, 2021; AfDB, 2020).

This article will delve into specific sustainable finance initiatives in Asia and Africa, conduct a comparative analysis of their impact, and explore collaboration avenues for a sustainable future.

Statement of the Problem

Despite the growing momentum of sustainable finance initiatives in Asia and Africa, several challenges hinder the effective implementation and scale-up of these efforts. Understanding and addressing these challenges is essential for achieving the desired outcomes of sustainable finance and advancing global sustainability goals.

One of the key challenges is the lack of harmonized regulatory frameworks and policy incentives for sustainable finance across countries within each region and between Asia and Africa. While individual countries have made strides in developing their sustainable finance policies, the absence of a standardized approach hampers cross-border investments and limits the scalability of sustainable finance initiatives. For instance, in Asia, countries such as China and India have introduced their own green bond guidelines and sustainable finance regulations (People's Bank of China, 2015; Securities and Exchange Board of India, 2020), but there is a need for greater alignment and coordination to facilitate regional collaboration.

In Africa, the absence of comprehensive sustainable finance policies and the limited availability of financing options pose significant challenges. Many African countries lack the necessary regulatory frameworks and institutional capacity to promote sustainable finance effectively. However, there have been notable efforts to address this issue. The African Development Bank's Sustainable Finance Framework (African Development Bank, 2014) and the African Union's Agenda 2063 (African Union, 2015) provide strategic guidance for integrating sustainability into financial systems, but implementation at the national level remains a challenge.

Another critical challenge is the limited awareness and understanding of sustainable finance among various stakeholders, including financial institutions, investors, and businesses. Despite the growing interest in sustainable finance, there is still a lack of knowledge and capacity to assess and incorporate sustainability factors into investment decisions effectively. Enhancing financial literacy and promoting capacity-building programs are essential to ensure informed decision-making and promote sustainable finance practices. The United Nations Environment Programme's Principles for Responsible Banking (United Nations Environment Programme Finance Initiative, 2019) and the International Finance Corporation's Performance Standards on Environmental and Social Sustainability (International Finance Corporation, 2012) outline guidelines for financial institutions to integrate sustainability into their operations. However, there is a need for greater dissemination and implementation of these principles across Asia and Africa. Furthermore, the availability of reliable and standardized data for assessing the environmental and social impact of sustainable finance initiatives remains a challenge. Access to accurate data is crucial for measuring progress, conducting impact assessments, and ensuring transparency and accountability. Efforts such as the Task Force on Climate-related Financial Disclosures (TCFD, 2017) have made strides in promoting climate-related data disclosure, but there is a need for similar initiatives focused on broader sustainability metrics.

Addressing these challenges requires concerted efforts from governments, financial institutions, and international organizations to develop and implement comprehensive regulatory frameworks, enhance capacity-building initiatives, and promote data transparency. Collaboration between Asia and Africa can play a pivotal role in sharing experiences, exchanging best practices, and collectively addressing these challenges to accelerate the transition towards sustainable finance and global sustainability.

In the subsequent sections, this article will explore the specific sustainable finance initiatives in Asia and Africa, conduct a comparative analysis of their impact and effectiveness, and propose recommendations for addressing the identified challenges. By referencing real policy documents and frameworks, this article aims to provide a robust and evidence-based analysis of the problem at hand.

Research Objectives and Scope

The primary objective of this research is to conduct a comparative analysis of sustainable finance initiatives in Asia and Africa, with a focus on their contribution to global sustainability. The study aims to explore the similarities, differences, challenges, and opportunities associated with sustainable finance practices in both regions. By examining the progress, impact, and effectiveness of these initiatives, the research seeks to identify lessons learned, best practices, and areas for improvement.

The specific research objectives are as follows:

To examine the current state of sustainable finance initiatives in Asia and Africa, including an overview of the policies, regulations, and frameworks implemented by governments, financial institutions, and international organizations.

1. To identify and analyze successful case studies of sustainable finance models in Asia and Africa, showcasing examples of effective implementation and positive outcomes.
2. To compare and contrast the key similarities and differences between sustainable finance initiatives in Asia and Africa, considering factors such as governance structures, regulatory frameworks, access to capital, technological advancements, and cultural norms.
3. To assess the impact and effectiveness of sustainable finance initiatives in both regions, evaluating their contribution to environmental sustainability, social development, and economic resilience.
4. To identify the challenges and barriers faced by sustainable finance initiatives in Asia and Africa, including regulatory gaps, capacity constraints, limited awareness, and data availability.
5. To propose recommendations and strategies for enhancing sustainable finance practices in both regions, taking into account the identified challenges and leveraging potential synergies between Asia and Africa.

The research scope encompasses an analysis of sustainable finance initiatives implemented by various stakeholders, including governments, financial institutions, and international organizations, in Asia and Africa. It covers a wide range of sustainable finance mechanisms, such as green bonds, sustainable lending, impact investing, and innovative financing mechanisms for sustainable development projects.

The study will primarily rely on a comprehensive review of existing literature, policy documents, reports, and case studies related to sustainable finance initiatives in Asia and Africa. Data analysis and qualitative research methods will be employed to examine the impact and effectiveness of these initiatives. However, it is important to note that this research will not delve into specific financial market dynamics or conduct a comprehensive financial analysis of individual countries or institutions.

By fulfilling these research objectives within the defined scope, this study aims to contribute to the existing knowledge on sustainable finance in Asia and Africa, provide insights for policymakers, practitioners, and researchers, and offer recommendations to advance the path towards global sustainability.

Literature review

Sustainable Finance Initiatives in Asia

Overview of Sustainable Finance in Asia

Asia has witnessed a significant rise in sustainable finance initiatives, driven by the region's growing recognition of the need to address environmental and social challenges while fostering economic growth. This section provides an overview of sustainable finance in Asia, highlighting key trends, regulatory frameworks, and regional initiatives.

Asian countries are increasingly adopting policies and regulations that promote sustainable finance practices. For instance, China has made substantial progress in integrating environmental considerations into its financial system. The People's Bank of China has issued guidelines on green finance and established a green bond market, facilitating investments in renewable energy, energy efficiency, and pollution control (People's Bank of China, 2016).

Similarly, in India, the Securities and Exchange Board of India (SEBI) has introduced guidelines for the issuance of green bonds, encouraging companies to raise capital for sustainable projects. Additionally, the Reserve Bank of India has implemented a Sustainable Finance Framework to promote green lending and sustainability-linked loans (Securities and Exchange Board of India, 2017; Reserve Bank of India, 2020).

Japan has been at the forefront of sustainable finance in Asia, with a long history of promoting environmentally and socially responsible investments. The Japan Sustainable Investment Forum (JSIF) has been instrumental in driving sustainable finance practices, bringing together investors, companies, and policymakers to collaborate on sustainable investment strategies (Japan Sustainable Investment Forum, n.d.).

Regional initiatives in Asia are also playing a crucial role in advancing sustainable finance. The Association of Southeast Asian Nations (ASEAN) has established the ASEAN Green Bond Standards, providing guidelines for issuers and investors in the region. This initiative aims to facilitate the development of a robust green bond market in Southeast Asia (ASEAN Capital Markets Forum, 2017).

Furthermore, the Asian Development Bank (ADB) has been actively promoting sustainable finance in the region. The ADB's Action Plan for Sustainable Finance outlines strategies to mobilize resources for sustainable infrastructure, enhance climate and environmental risk management, and promote financial inclusion (Asian Development Bank, 2017).

Asian financial institutions are increasingly incorporating sustainability considerations into their operations. For example, the Development Bank of Singapore (DBS) has implemented a Sustainable Finance Framework, guiding its lending and investment activities towards sustainable projects (Development Bank of Singapore, 2019).

In summary, Asia is experiencing a significant surge in sustainable finance initiatives, driven by regulatory frameworks, regional initiatives, and the proactive engagement of financial institutions. Countries like China, India, and Japan are leading the way in integrating sustainable finance practices into their financial systems. Regional collaborations and initiatives by organizations such as ASEAN and ADB further support the development of sustainable finance in Asia, contributing to the region's transition towards a more sustainable and resilient future.

Sustainable Finance Initiatives in Asia

Asia has witnessed a surge in sustainable finance initiatives, with various countries and organizations in the region actively promoting environmentally and socially responsible investment practices. This section provides an overview of key sustainable finance initiatives in Asia, highlighting specific projects and programs that have made significant contributions to the region's sustainability goals.

China, as the world's largest emitter of greenhouse gases, has taken substantial steps to advance sustainable finance. One noteworthy initiative is the establishment of the Green Finance Committee (GFC) by the China Society for Finance and Banking. The GFC aims to promote green finance practices, conduct research, and facilitate knowledge sharing among financial institutions (China Society for Finance and Banking, n.d.).

In India, the Indian Renewable Energy Development Agency (IREDA) plays a crucial role in promoting sustainable finance. IREDA provides financial assistance and incentives for renewable energy projects, including solar, wind, and hydroelectric power. By offering favorable loan terms and financial support, IREDA has played a significant role in facilitating the growth of renewable energy investments in India (Indian Renewable Energy Development Agency, n.d.).

Japan has been a leader in sustainable finance initiatives, particularly through the issuance of green bonds. One prominent example is the issuance of green bonds by the Tokyo Metropolitan Government. The proceeds from these bonds are allocated to projects aimed at reducing greenhouse gas emissions, improving energy efficiency, and promoting environmental conservation (Tokyo Metropolitan Government, n.d.).

The Monetary Authority of Singapore (MAS) has also made significant efforts to foster sustainable finance in the region. MAS launched the Green Finance Action Plan in 2019, with the aim of developing Singapore as a leading hub for green finance. The plan includes initiatives such as introducing a green bond grant scheme and developing guidelines for sustainability-linked loans, encouraging financial institutions to incorporate sustainability considerations into their lending practices (Monetary Authority of Singapore, 2019).

Regional collaborations have also played a crucial role in promoting sustainable finance in Asia. The Asian Infrastructure Investment Bank (AIIB) has been actively financing sustainable infrastructure projects across the region. Through its Sustainable Energy for Asia Strategy, the AIIB supports investments in renewable energy, energy efficiency, and low-carbon transportation projects (Asian Infrastructure Investment Bank, 2022.).

In summary, sustainable finance initiatives in Asia are diverse and multifaceted, with various countries and organizations driving the adoption of environmentally and socially responsible investment practices. Initiatives such as the Green Finance Committee in China, the Indian Renewable Energy Development Agency in India, and the issuance of green bonds in Japan have demonstrated the region's commitment to sustainable finance. Regional collaborations, exemplified by the efforts of the Monetary Authority of Singapore and the Asian Infrastructure Investment Bank, further contribute to the growth and development of sustainable finance in Asia.

Case Studies: Successful Sustainable Finance Models in Asia

Asia has witnessed the emergence of successful sustainable finance models that have demonstrated the viability and effectiveness of integrating environmental and social considerations into financial practices. This section presents case studies of notable sustainable finance models in Asia, showcasing their innovative approaches and positive impacts on sustainable development.

Case Study 1: The Green Energy Financing Model in China

China has been at the forefront of sustainable finance, particularly in the renewable energy sector. The Green Energy Financing Model, implemented by the Industrial and Commercial Bank of China (ICBC), has successfully facilitated the financing of renewable energy projects. Through this model, ICBC provides long-term, low-interest loans to renewable energy companies, incentivizing investment in solar, wind, and hydroelectric power projects. This has led to a significant increase in renewable energy capacity and a reduction in carbon emissions in China (World Resources Institute, 2018).

Case Study 2: Sustainable Microfinance in Bangladesh

Grameen Bank, founded by Nobel laureate Muhammad Yunus, has pioneered sustainable microfinance in Bangladesh. By providing small loans to low-income individuals, particularly women, Grameen Bank enables them to start sustainable businesses and improve their livelihoods. The bank incorporates social and environmental considerations into its lending practices, emphasizing projects that promote renewable energy, sustainable agriculture, and clean water access. This sustainable microfinance model has not only lifted many people out of poverty but also contributed to environmental conservation and social empowerment (Grameen Bank, n.d.).

Case Study 3: Green Bond Initiatives in Singapore

Singapore has embraced green finance, and several successful green bond initiatives have been launched in the country. One notable example is the issuance of green bonds by CapitaLand Limited, a real estate company. The proceeds from these bonds are allocated to financing and refinancing green buildings and sustainable development projects. CapitaLand's green bond initiatives have contributed to the construction of energy-efficient buildings, reduced carbon emissions, and enhanced sustainable urban development in Singapore (CapitaLand Limited, 2020).

Case Study 4: Sustainable Infrastructure Financing in India

India's National Investment and Infrastructure Fund (NIIF) has played a pivotal role in promoting sustainable infrastructure financing in the country. The NIIF has established the NIIF Green Growth Equity Fund (GGF), which focuses on investments in green infrastructure projects, such as renewable energy, clean transportation, and waste management. By attracting private investments and providing capital for sustainable infrastructure, the GGF has accelerated India's transition towards a low-carbon economy (National Investment and Infrastructure Fund, n.d.).

These case studies highlight successful sustainable finance models in Asia that have demonstrated tangible environmental and social benefits. The Green Energy Financing Model in China, sustainable microfinance in Bangladesh, green bond initiatives in Singapore, and sustainable infrastructure financing in India exemplify innovative approaches to integrating sustainability into financial practices.

Challenges and Opportunities in Asian Sustainable Finance Initiatives

Asia's sustainable finance initiatives face several challenges, but they also present significant opportunities for transformative change. One key challenge is the limited awareness and understanding of sustainable finance among stakeholders. Many financial institutions, investors, and the general public in Asia lack awareness of the potential benefits and financial opportunities that sustainable finance offers (United Nations Environment Programme, 2018). This highlights the need for increased awareness campaigns and educational programs to promote understanding and adoption of sustainable finance principles.

Another challenge lies in the establishment of consistent regulatory frameworks and standards across Asian countries. Harmonized regulations and standardized sustainability reporting requirements are crucial for ensuring transparency and comparability of sustainable finance initiatives. Developing clear guidelines will provide a common foundation and encourage the integration of environmental, social, and governance (ESG) factors into financial decision-making (Financial Stability Board, 2020).

Access to financing is a persistent challenge, particularly for small and medium-sized enterprises (SMEs) and projects in less developed regions. Limited access to affordable capital, lack of collateral, and high transaction costs hinder the flow of funds to sustainable projects. Addressing these barriers requires innovative financing mechanisms, such as blended finance models and targeted financial support for underserved sectors (Asian Development Bank, 2021).

Despite these challenges, there are significant opportunities to further enhance sustainable finance initiatives in Asia. The issuance of green bonds and the development of sustainable investment products offer avenues to mobilize capital for climate-friendly projects. Green bonds have gained traction globally and can attract investments specifically earmarked for environmental initiatives. Moreover, the creation of sustainable investment products, such as green funds and sustainability-themed indexes, can cater to the growing demand for socially and environmentally responsible investment options (Climate Bonds Initiative, 2021).

Collaboration and knowledge sharing are critical drivers of progress in sustainable finance. Encouraging collaboration among stakeholders, including financial institutions, governments, academia, and civil society, can foster knowledge sharing, capacity building, and the adoption of best practices. Regional collaborations, partnerships, and knowledge-sharing platforms can facilitate the exchange of experiences and accelerate the growth of sustainable finance in Asia (Sustainable Finance Study Group, 2020).

Technology integration also offers immense opportunities for advancing sustainable finance in Asia. Leveraging technologies such as blockchain, artificial intelligence, and data analytics can enhance efficiency, transparency, and risk assessment in sustainable finance practices. These technologies can enable better assessment of environmental and social risks, improve the tracking of funds, and facilitate the verification of sustainable outcomes (United Nations Economic and Social Commission for Asia and the Pacific, 2019).

By addressing the challenges and embracing the opportunities, Asian countries can unlock the full potential of sustainable finance and pave the way for a more sustainable and resilient future.

Sustainable Finance Initiatives in Africa

Overview of Sustainable Finance

Sustainable finance is a critical component of achieving global sustainability goals, and Africa has been making significant strides in this area. The continent is increasingly recognizing the importance of integrating environmental, social, and governance (ESG) factors into financial practices to drive sustainable development. This section provides an overview of sustainable finance in Africa, highlighting key initiatives and trends.

In recent years, African countries have witnessed the emergence of sustainable finance frameworks and policies that promote responsible investment and sustainable economic growth. The African Development Bank (AfDB) has been at the forefront of sustainable finance initiatives on the continent. The bank has developed several programs and financing mechanisms aimed at supporting sustainable projects, such as renewable energy, climate resilience, and sustainable infrastructure (African Development Bank, 2023).

One notable sustainable finance initiative in Africa is the establishment of green bonds. Green bonds provide a mechanism for raising capital specifically for environmentally friendly projects. South Africa, Nigeria, and Kenya have been pioneers in issuing green bonds to finance renewable energy projects, sustainable agriculture, and climate change adaptation initiatives (Climate Bonds Initiative, 2021). These green bond issuances not only attract domestic and international investors but also contribute to addressing Africa's pressing environmental challenges.

Another significant trend in African sustainable finance is the rise of impact investing. Impact investing involves directing investments towards projects and companies that generate positive social and environmental outcomes alongside financial returns. Impact investors in Africa are actively seeking opportunities that align with the United Nations Sustainable Development Goals (SDGs) to address pressing social and environmental issues while driving economic growth (Global Impact Investing Network, 2021).

Furthermore, African financial institutions are increasingly incorporating ESG considerations into their investment decision-making processes. This integration involves assessing the environmental and social risks and opportunities associated with investments, as well as considering corporate governance practices. By incorporating ESG factors, African financial institutions are not only promoting sustainable practices but also mitigating risks and enhancing long-term financial performance (United Nations Economic Commission for Africa, 2021).

However, despite the progress made, Africa faces several challenges in advancing sustainable finance. Limited access to finance, inadequate regulatory frameworks, and lack of awareness and capacity are some of the obstacles hindering the widespread adoption of sustainable finance practices across the continent. Addressing these challenges requires collaborative efforts among governments, financial institutions, and international organizations to develop supportive policies, improve financial infrastructure, and enhance awareness and capacity-building initiatives (United Nations Environment Programme, 2020).

In conclusion, Africa is witnessing a growing momentum in sustainable finance, with initiatives such as green bonds, impact investing, and the integration of ESG factors gaining traction. The continent's commitment to sustainable development, along with targeted policies and collaborative efforts, will be key in unlocking the full potential of sustainable finance in Africa and driving positive environmental, social, and economic outcomes.

Sustainable Finance Initiatives in Africa

Africa is witnessing a growing emphasis on sustainable finance, with various initiatives aimed at promoting responsible investment and driving sustainable development on the continent. This section provides an overview of sustainable finance initiatives in Africa, highlighting key programs and trends.

The African Development Bank (AfDB) has been instrumental in driving sustainable finance initiatives across Africa. The bank has launched several programs and financing mechanisms to support sustainable projects and foster economic growth. One notable initiative is the Africa Green Growth Fund, which provides financial and technical support to projects focused on renewable energy, climate adaptation, and sustainable infrastructure (African Development Bank, 2021). The AfDB's commitment to sustainable finance plays a vital role in mobilizing resources and fostering collaboration among stakeholders in Africa.

In addition to the AfDB's efforts, African countries are increasingly recognizing the importance of sustainable finance and incorporating it into their national agendas. Many countries have developed national sustainable finance frameworks and policies to promote responsible investment and environmental stewardship. For example, Kenya has implemented the Green Economy Strategy and Implementation Plan, which aims to mobilize investments for sustainable sectors and transition to a low-carbon, resource-efficient economy (Republic of Kenya, 2012).

Green bonds have gained significant traction in Africa as a means to finance sustainable projects. South Africa, Nigeria, and Kenya have been at the forefront of green bond issuances on the continent. For instance, South Africa's Eskom issued the continent's first green bond in 2019 to fund renewable energy projects, while Nigeria's Access Bank and Kenya's Nairobi Securities Exchange have also successfully issued green bonds (Climate Bonds Initiative, 2021). These green bond initiatives attract both domestic and international investors and contribute to addressing Africa's environmental challenges.

Furthermore, impact investing is gaining momentum in Africa. Impact investing involves directing investments towards projects and enterprises that generate measurable social and environmental impacts alongside financial returns. Africa's rich social and environmental challenges provide ample opportunities for impact investors to drive positive change. Impact investment funds, such as the African Agriculture Impact Investment Fund, focus on supporting sustainable agriculture, improving food security, and empowering rural communities (Global Impact Investing Network, 2021). These initiatives not only generate financial returns but also create tangible social and environmental benefits.

Despite the progress, Africa still faces challenges in scaling up sustainable finance initiatives. Limited access to finance, inadequate regulatory frameworks, and the need for capacity-building are key barriers that need to be addressed. Collaboration between governments, financial institutions, and international organizations is crucial in developing enabling policies, improving financial infrastructure, and enhancing awareness and knowledge sharing (United Nations Environment Programme, 2020).

In conclusion, sustainable finance initiatives in Africa are gaining momentum, driven by the efforts of organizations like the African Development Bank and national governments. Green bonds and impact investing are playing pivotal roles in mobilizing capital for sustainable projects and generating positive social and environmental impacts. However, addressing the challenges and fostering collaboration will be essential in realizing the full potential of sustainable finance in Africa and driving inclusive and sustainable development across the continent.

Case Studies: Successful Sustainable Finance Models in Africa

Africa has witnessed the emergence of several successful sustainable finance models that showcase the continent's commitment to addressing environmental and social challenges while promoting economic growth. These case studies demonstrate the effectiveness of sustainable finance in driving positive impact and transforming industries.

Case Study 1: M-KOPA Solar - A Revolutionary Pay-as-You-Go Solar Model

M-KOPA Solar, a Kenyan-based company, has revolutionized the access to clean energy in East Africa through its innovative pay-as-you-go solar model. The company provides affordable solar home systems to off-grid households, enabling them to access clean energy for lighting, charging mobile devices, and powering small appliances. M-KOPA Solar's model allows customers to make small, affordable payments through mobile money platforms until they fully own the solar system (M-KOPA, 2021).

This sustainable finance model addresses the financing barriers that often hinder access to renewable energy solutions for underserved communities. By combining mobile payment technology with renewable energy products, M-KOPA Solar has reached over a million households in Kenya, Uganda, and Tanzania, contributing to reduced reliance on fossil fuels and improved energy access for rural populations (Gallagher, 2017).

Case Study 2: Nedbank's Green Bond - Financing Renewable Energy Projects

Nedbank, one of South Africa's largest banks, issued Africa's first corporate green bond in 2019. The bond raised 1.7 billion South African Rand (approximately $120 million) and was earmarked for financing renewable energy and energy-efficient projects. The bond's proceeds supported projects that promote sustainability and reduce carbon emissions, including renewable energy installations and energy-efficient buildings (Nedbank, 2019).

By issuing the green bond, Nedbank demonstrated its commitment to sustainable finance and catalyzed investments in environmentally friendly projects. The bond attracted investors seeking both financial returns and positive environmental impacts. The success of Nedbank's green bond has paved the way for other financial institutions in Africa to explore sustainable debt instruments and mobilize capital for climate-friendly initiatives (Pereira, 2019).

Case Study 3: Rwanda's Green Growth Strategy - Integrating Sustainable Finance in National Development

Rwanda has made remarkable progress in promoting sustainable finance at the national level. The country's Green Growth Strategy is a comprehensive framework that integrates sustainable finance principles into its development agenda. Rwanda's strategy includes a dedicated green fund, the Rwanda Green Fund (FONERWA), which finances projects aligned with the country's climate and environmental objectives (Government of Rwanda, 2011).

FONERWA has been instrumental in supporting projects in various sectors, such as renewable energy, sustainable agriculture, and waste management. The fund mobilizes both domestic and international investments to drive green initiatives and create a sustainable future for Rwanda. By prioritizing sustainable finance, Rwanda is demonstrating how integrating environmental considerations into national development planning can drive positive outcomes for both people and the planet (FONERWA, 2021).

In conclusion, these case studies exemplify successful sustainable finance models in Africa that have delivered tangible environmental and social benefits. M-KOPA Solar's pay-as-you-go solar model has expanded energy access to off-grid households, Nedbank's green bond has mobilized funds for renewable energy projects, and Rwanda's Green Growth Strategy has integrated sustainable finance principles into national development planning. These examples showcase the transformative power of sustainable finance in Africa, demonstrating its potential to drive inclusive and sustainable development across the continent.

Challenges and Opportunities in African Sustainable Finance Initiatives

Africa's sustainable finance initiatives face a range of challenges and opportunities that shape their future trajectory. Overcoming these obstacles and capitalizing on the potential opportunities will be crucial for the advancement and success of sustainable finance in Africa.

One of the primary challenges facing sustainable finance initiatives in Africa is the limited access to finance for many individuals and businesses. Financial inclusion remains a significant hurdle, particularly for small and medium-sized enterprises (SMEs) and rural communities. The lack of accessible financial services hinders the adoption of sustainable practices, as financial resources are often required to implement environmentally friendly projects. Innovative financial products and services that cater to the needs of underserved populations are necessary to address this challenge and unlock the potential of sustainable finance in Africa (United Nations Economic Commission for Africa, 2021).

Inadequate regulatory frameworks pose another obstacle to the growth of sustainable finance in Africa. Many African countries face regulatory gaps and inconsistencies that deter investors and financial institutions from engaging in sustainable projects. The absence of clear and supportive policies hampers the flow of investments into sustainable initiatives. To foster sustainable finance, it is essential to harmonize regulatory frameworks across countries and create an enabling environment that encourages and supports sustainable investments (African Development Bank, 2021).

Lack of awareness and capacity among stakeholders is also a significant barrier to the widespread adoption of sustainable finance in Africa. Many businesses, investors, and policymakers may not fully understand the potential benefits and mechanisms of sustainable finance. To address this, capacity-building programs, workshops, and educational campaigns are necessary to enhance knowledge and awareness of sustainable finance practices. Increasing awareness and building the necessary capacity will help stakeholders embrace sustainable finance principles and drive sustainable development on the continent (United Nations Environment Programme, 2020).

Despite these challenges, African sustainable finance initiatives offer significant opportunities for driving positive change and fostering sustainable development. Africa's abundance of natural resources presents an opportunity to leverage sustainable finance for investments in renewable energy, sustainable agriculture, and responsible mining. By directing capital towards these sectors, economic growth can be achieved while promoting environmental conservation and climate resilience (African Development Bank, 2021).

Furthermore, Africa's diverse social and environmental challenges provide fertile ground for impact investing. Impact investors can make a meaningful difference by directing capital towards projects that address poverty, access to clean water, healthcare, and other pressing social and environmental issues. Impact investing not only generates financial returns but also delivers tangible social and environmental impacts (Global Impact Investing Network, 2021).

The rise of digital technology and mobile payments in Africa offers unique opportunities for sustainable finance. Fintech solutions can play a pivotal role in expanding financial access, facilitating green bond issuances, and supporting pay-as-you-go models for renewable energy. By embracing technology, African countries can unlock new avenues for sustainable finance, making it more accessible, efficient, and inclusive (Pereira, 2021).

Collaborative partnerships between governments, financial institutions, international organizations, and civil society are essential for advancing sustainable finance in Africa. Multilateral partnerships can mobilize resources, share best practices, and provide technical assistance to address the challenges and capitalize on the opportunities in sustainable finance. By working together, stakeholders can create an ecosystem that supports the growth and success of sustainable finance initiatives across the continent (Government of Rwanda, 2011).

In conclusion, while challenges exist, African sustainable finance initiatives offer tremendous potential for driving positive change and fostering sustainable development. Overcoming limited access to finance, addressing regulatory gaps, and increasing awareness are essential for unlocking the full potential of sustainable finance in Africa. By leveraging natural resources, embracing impact investing, harnessing technology, and fostering collaborative partnerships, Africa can pave the way for transformative and inclusive development through sustainable finance.

Methodology

To achieve the research objectives of conducting a comparative analysis of sustainable finance initiatives in

Asia and Africa, a theoretical approach will be employed. The methodology will primarily rely on a comprehensive review of existing literature, including academic journals, policy documents, reports, and other relevant sources, to gather theoretical insights on sustainable finance in both regions.

The research will begin with a thorough literature review, which will provide the foundation for understanding key concepts, frameworks, and theoretical perspectives related to sustainable finance initiatives in Asia and Africa (Dixon et al., 2021; UNESCAP, 2022; AfDB, 2021). This review will encompass a wide range of sources to ensure a comprehensive understanding of the theoretical landscape.

Based on the insights gained from the literature review, a conceptual framework will be developed to guide the analysis of sustainable finance initiatives. This framework will outline the key dimensions, variables, and relationships that will be explored in the comparative analysis (IUCN, 2021; GRI, 2021).

The comparative analysis will focus on identifying and comparing theoretical approaches, policies, and frameworks related to sustainable finance in Asia and Africa (ADB, 2020; UNEP, 2020). This analysis will delve into the similarities, differences, challenges, and opportunities associated with promoting sustainable finance in both regions. By examining the theoretical foundations, the study aims to provide a comprehensive understanding of the theoretical landscape of sustainable finance in Asia and Africa.

The findings from the comparative analysis will be synthesized to identify theoretical patterns, trends, and potential theoretical frameworks that can enhance our understanding of sustainable finance initiatives (UNDP, 2020; ILO, 2021). This synthesis will involve critically analyzing and interpreting the theoretical concepts and perspectives identified in the literature, drawing connections and insights from the theoretical approaches employed in both regions.

Based on the theoretical insights and synthesis, theoretical recommendations will be proposed to address the challenges and enhance the effectiveness of sustainable finance initiatives in Asia and Africa (UNEP FI, 2021; UNECA, 2020). These recommendations will be formulated based on the theoretical frameworks and concepts derived from the comparative analysis. They will aim to contribute to the theoretical understanding of sustainable finance and offer guidance for future theoretical research.

The study will conclude by summarizing the key theoretical findings, implications, and potential avenues for further theoretical research (World Bank, 2021; IFC, 2022). The conclusion will provide a theoretical perspective on the comparative analysis of sustainable finance initiatives in Asia and Africa, highlighting the significance of theoretical frameworks in advancing the understanding and implementation of sustainable finance practices.

In summary, this research will employ a theoretical approach through a comprehensive literature review, development of a conceptual framework, comparative analysis of theoretical approaches, synthesis of theoretical insights, and the formulation of theoretical recommendations. By focusing on theoretical perspectives, this study aims to contribute to the theoretical understanding of sustainable finance initiatives in Asia and Africa, providing valuable insights and guidance for future research in this field.

Results and Discussions

Comparative Analysis of Sustainable Finance Initiatives

Key Similarities and Differences between Asia and Africa

Asia and Africa, two vast continents, have distinct characteristics and unique approaches to sustainable finance. While both regions strive for economic growth and environmental sustainability, there are significant similarities and differences in their approaches to sustainable finance.

One key similarity between Asia and Africa is the recognition of the importance of sustainable development. Both regions acknowledge the need to balance economic progress with environmental and social considerations. Sustainable finance initiatives in both Asia and Africa aim to promote investments that generate positive environmental and social impacts while ensuring financial stability and profitability.

However, there are notable differences in the context and priorities of sustainable finance between Asia and Africa. Asia, with its diverse economies ranging from advanced nations to emerging markets, has witnessed rapid industrialization and urbanization. Sustainable finance initiatives in Asia often focus on addressing environmental challenges such as pollution, resource depletion, and climate change. The emphasis is on promoting clean energy, green infrastructure, and sustainable urban development to mitigate the environmental impact of rapid economic growth.

On the other hand, Africa faces unique challenges in sustainable development. The continent grapples with issues such as poverty, limited access to basic services, and the need for inclusive economic growth. Consequently, sustainable finance initiatives in Africa often prioritize social development alongside environmental considerations. Projects may aim to improve access to clean water, healthcare, education, and renewable energy for marginalized communities. The focus is on achieving sustainable development goals while addressing social inequalities and promoting inclusive growth.

Another difference lies in the level of financial market development and regulatory frameworks. Asia boasts well-established financial markets and institutions, which have facilitated the growth of sustainable finance. The region has witnessed the issuance of green bonds, the establishment of sustainable investment funds, and the integration of environmental, social, and governance (ESG) criteria into investment practices. In contrast, Africa's financial markets are still developing, and regulatory frameworks for sustainable finance are at an early stage. Efforts are being made to create enabling environments for sustainable finance, but there is a need for further capacity-building and regulatory harmonization to accelerate progress.

Furthermore, the sources of financing differ between Asia and Africa. In Asia, both domestic and international sources contribute to sustainable finance initiatives. Asian countries attract significant investments from institutional investors, development banks, and impact investors who recognize the region's potential for sustainable growth. In contrast, Africa relies more heavily on international development assistance and partnerships with multilateral organizations and donor countries. African countries are actively seeking to attract private investment and mobilize domestic resources to drive sustainable finance initiatives.

In conclusion, while Asia and Africa share a common goal of achieving sustainable development through finance, there are notable similarities and differences in their approaches. Both regions recognize the importance of balancing economic growth with environmental and social considerations. However, the specific priorities, challenges, and sources of financing differ. Understanding these similarities and differences is crucial for policymakers, investors, and stakeholders to tailor their approaches to sustainable finance based on the unique contexts of Asia and Africa.

Comparative Assessment of the Impact and Effectiveness of Initiatives

Assessing the impact and effectiveness of sustainable finance initiatives in both Asia and Africa is essential to understand their contribution to global sustainability and to identify areas for improvement. These initiatives play a critical role in promoting environmentally and socially responsible investments, but their outcomes may vary due to differences in regional contexts, regulatory environments, and financial market development.

In Asia, sustainable finance initiatives have witnessed significant growth and impact in recent years. Countries like China, Japan, and South Korea have been at the forefront of sustainable finance, embracing green bonds, sustainable investment funds, and integrating ESG criteria into their investment practices. The issuance of green bonds, in particular, has surged, channeling funds towards renewable energy projects, green infrastructure, and climate-friendly initiatives. As a result, Asia has made considerable strides in addressing environmental challenges and promoting sustainable development (United Nations Environment Programme, 2020).

Moreover, Asian sustainable finance initiatives have not only driven positive environmental outcomes but also contributed to economic growth and job creation. Investments in green technologies and sustainable businesses have stimulated innovation and competitiveness, fostering a transition to low-carbon and resource-efficient economies. Additionally, sustainable finance has attracted interest from global investors seeking responsible and impactful investment opportunities in Asia's emerging markets (Sawhney et al., 2022).

However, challenges persist, such as the need for consistent reporting standards, data transparency, and better alignment of sustainable finance efforts with regional development priorities. Asian countries must continue to strengthen regulatory frameworks and collaboration between governments, financial institutions, and the private sector to maximize the impact and effectiveness of sustainable finance initiatives (Asian Development Bank, 2021).

In Africa, sustainable finance initiatives have shown promising potential to address pressing social and environmental issues. Despite facing significant challenges related to financial market development and regulatory frameworks, the continent has made efforts to mobilize resources for sustainable development through partnerships and international assistance (United Nations Economic Commission for Africa, 2021).

African sustainable finance initiatives often focus on projects that prioritize social development, poverty reduction, and access to basic services. Investments in clean energy, water and sanitation, healthcare, and education have the potential to uplift underserved communities and foster inclusive growth. Moreover, the rise of impact investing in Africa has attracted private capital towards projects that generate both financial returns and positive social and environmental impacts (Global Impact Investing Network, 2021).

However, the impact and effectiveness of African sustainable finance initiatives can be hindered by limited financial access, inadequate infrastructure, and political instability in some regions. Unlocking the full potential of sustainable finance in Africa requires targeted efforts to improve financial inclusion, strengthen regulatory frameworks, and address governance challenges (African Development Bank, 2021).

In conclusion, sustainable finance initiatives in both Asia and Africa have demonstrated their potential to drive positive change and contribute to global sustainability. While each region faces distinct challenges and priorities, the common goal of achieving sustainable development unites them. By continuously evaluating and enhancing the impact and effectiveness of these initiatives, Asia and Africa can play a pivotal role in advancing the global sustainability agenda.

Lessons Learned and Best Practices from Both Regions

Sustainable finance initiatives in Asia and Africa have provided valuable lessons and best practices that can guide future efforts towards global sustainability. One of the fundamental takeaways is the power of collaboration among various stakeholders. In both regions, successful sustainable finance initiatives have involved partnerships between governments, financial institutions, civil society organizations, and the private sector. By working together, these stakeholders can leverage their expertise, resources, and networks to mobilize sustainable investments and address complex sustainability challenges.

A key aspect of driving sustainable finance is the establishment of robust regulatory frameworks. Both Asia and Africa have recognized the importance of creating an enabling environment through policy and regulation. Implementing clear guidelines, standards, and incentives can encourage responsible investment practices, facilitate transparency, and ensure accountability. Furthermore, regulatory frameworks should be adaptive and supportive, considering the unique needs and priorities of each region.

Financial innovation has played a pivotal role in advancing sustainable finance in both regions. Developing new financial instruments and mechanisms, such as green bonds, impact investment funds, and sustainability-linked loans, has attracted capital towards environmentally and socially responsible projects. Encouraging financial institutions to adopt Environmental, Social, and Governance (ESG) criteria in their investment decision-making processes has also been instrumental in promoting sustainable finance.

A crucial aspect that underpins the success of sustainable finance initiatives is capacity building. Building institutional and human capacity is essential for their effective implementation. Both Asia and Africa have emphasized the importance of knowledge sharing, training programs, and technical assistance to enhance expertise in sustainable finance practices. By investing in capacity building, governments and organizations can foster a culture of sustainability and equip individuals with the skills needed to drive positive change.

Accurate and transparent data play a crucial role in assessing the impact and effectiveness of sustainable finance initiatives. Both regions have recognized the need for standardized reporting frameworks and reliable data sources. By improving data collection, measurement, and reporting mechanisms, stakeholders can better track the environmental and social outcomes of sustainable investments, identify areas for improvement, and demonstrate the value of sustainable finance to investors and the public.

Finally, one of the critical takeaways is the importance of localization and contextualization. While global best practices are valuable, it is essential to tailor sustainable finance initiatives to local contexts and priorities. Lessons learned from both Asia and Africa highlight the importance of understanding the unique socio-economic and environmental challenges faced by each region. By taking into account local needs, cultural considerations, and development aspirations, sustainable finance initiatives can be better aligned with national strategies and have a more significant impact on the ground.

In conclusion, the sustainable finance initiatives in Asia and Africa have yielded valuable lessons and best practices that can inform future endeavors towards global sustainability. Collaboration, robust regulatory frameworks, financial innovation, capacity building, data transparency, and contextualization are key elements that have emerged as crucial success factors. By learning from these experiences and continuously adapting approaches, stakeholders can enhance the impact and effectiveness of sustainable finance initiatives, contributing to a more sustainable future for both regions and the world at large.

Conclusions and Recommendations

A Path towards Global Sustainability

Synergies and Collaboration between Asia and Africa

Asia and Africa, as regions striving for sustainable development, can greatly benefit from synergies and collaboration in the field of sustainable finance. By leveraging their respective strengths and sharing knowledge and resources, they can enhance their collective efforts towards global sustainability.

One potential area of collaboration is knowledge exchange. Asia has made significant progress in sustainable finance, with well-established initiatives and experiences to share. Africa, on the other hand, can contribute its unique perspectives and innovative approaches to address sustainability challenges. Through knowledge sharing platforms, conferences, and joint research projects, the two regions can learn from each other's successes and failures, thus accelerating progress in sustainable finance.

Furthermore, collaboration can extend to joint initiatives and partnerships. By joining forces, Asian and African countries can create investment platforms that pool resources to fund impactful projects in both regions. Such collaboration can attract international investors and foster greater financial inclusivity for sustainable development initiatives. Additionally, partnerships between financial institutions, governments, and international organizations can facilitate the exchange of expertise, technical assistance, and financial support.

Recommendations for Enhancing Sustainable Finance Globally

To enhance sustainable finance globally, several recommendations can be considered. Firstly, policymakers should prioritize the development and implementation of clear regulatory frameworks that incentivize sustainable finance practices. These frameworks should provide guidance on reporting standards, disclosure requirements, and risk assessments related to environmental, social, and governance factors. Harmonizing these regulations across countries can facilitate cross-border investments and ensure a level playing field for sustainable finance initiatives.

Secondly, financial institutions should integrate sustainability considerations into their core business practices. This involves incorporating environmental and social risk assessments into investment decision-making processes, offering sustainable financial products, and promoting responsible lending and investment practices. Moreover, collaboration among financial institutions, including sharing best practices and knowledge, can foster innovation and standardization in sustainable finance.

Thirdly, capacity building programs should be implemented to equip stakeholders with the necessary skills and knowledge for sustainable finance. These programs should target policymakers, financial professionals, and entrepreneurs, providing training on sustainable investment strategies, risk assessment, and impact measurement. Additionally, educational institutions can play a crucial role in integrating sustainable finance principles into curricula, thus preparing future generations for the challenges and opportunities of sustainable finance.

Future Directions and Emerging Trends in Sustainable Finance

The future of sustainable finance holds great potential for further innovation and progress. Some emerging trends that are expected to shape the field include:

Green and Sustainable Bonds: The issuance of green and sustainable bonds is likely to increase, providing investors with more options to support environmentally friendly projects. This trend promotes transparency and accountability in financing sustainable initiatives.

Technology and Digital Solutions: Advancements in technology, such as blockchain and digital platforms, can improve efficiency, transparency, and accessibility in sustainable finance. These solutions facilitate the verification of sustainability credentials and enable broader participation from individual investors.

Impact Measurement and Reporting: The focus on impact measurement and reporting will intensify, with increased demand for standardized frameworks and methodologies. Improved measurement techniques will enhance the credibility and comparability of sustainable finance initiatives, allowing for better evaluation and decision-making.

Integration of ESG Factors: Environmental, social, and governance (ESG) factors will become increasingly integrated into mainstream investment practices. Investors will place greater importance on ESG considerations, and companies will be incentivized to improve their sustainability performance to attract investment.

Conclusion

In conclusion, the comparative analysis of sustainable finance initiatives in Asia and Africa reveals a promising path towards global sustainability. Both regions have shown commendable progress in promoting sustainable finance, and there exist valuable opportunities for collaboration and knowledge exchange to further advance the cause of sustainable development.

Asia, with its dynamic economies and increasing environmental awareness, has embraced sustainable finance as a catalyst for positive change (ADB, 2020; GRI, 2021). The region's success in implementing policies, regulations, and frameworks to incentivize sustainable investments, such as green bonds, sustainable lending, and impact investing, has demonstrated its commitment to addressing environmental challenges and promoting sustainable growth (UNESCAP, 2022; IFC, 2022). Furthermore, Asia's collaborative ethos, capacity building initiatives, and transparent data practices have been instrumental in achieving triumphs in sustainable finance (ESCAP, 2022; UNEP FI, 2021).

On the other hand, Africa, characterized by its immense potential and unique challenges, is making remarkable strides towards sustainable development through sustainable finance (UNDP, 2020; IUCN, 2021). Governments, international organizations, and financial institutions in Africa have recognized the transformative power of sustainable finance and have undertaken initiatives like microfinance for rural communities, innovative climate adaptation financing, and partnerships for sustainable agriculture and natural resource management (UNDP, 2020; GCF, 2022). These endeavors reflect Africa's commitment to addressing social inequalities and environmental vulnerabilities and leveraging sustainable finance as a means of inclusive growth and resilience.

By collaborating and leveraging each other's experiences and strengths, Asia and Africa can create synergies that drive progress towards global sustainability (AfDB, 2021; UNECA, 2020). Knowledge exchange and joint initiatives between the two regions can facilitate the sharing of best practices, successful models, and lessons learned, fostering a collective effort towards sustainable development goals (IUCN, 2021; GRI, 2021).

To enhance sustainable finance on a global scale, it is imperative to develop clear regulatory frameworks that provide certainty and stability for investors and businesses alike (World Bank, 2021; IFC, 2022). Effective regulations can help create an enabling environment for sustainable finance to thrive and ensure alignment with broader sustainability objectives. Additionally, promoting sustainable practices within financial institutions, such as integrating environmental, social, and governance (ESG) considerations into decision-making processes, can further embed sustainability in the core of financial activities (ADB, 2020; UNEP FI, 2021). Encouraging transparency and accountability in reporting on sustainable finance initiatives will also bolster stakeholders' confidence and facilitate effective impact measurement and evaluation (GRI, 2021; UNESCAP, 2022).

Capacity building is equally crucial in the journey towards sustainable finance success (UNECA, 2020; UNDP, 2020). By investing in comprehensive programs that equip stakeholders with the necessary knowledge and skills, governments, financial institutions, and businesses can navigate the complexities of sustainable finance and maximize its potential for positive change. Capacity building efforts should encompass various stakeholders, including policymakers, financial professionals, and community leaders, to build a holistic understanding and drive collective action (IUCN, 2021; IFC, 2022).

The future of sustainable finance holds immense promise and potential (UNEP, 2020; ADB, 2020). Trends such as the continued issuance of green and sustainable bonds will mobilize significant funds towards environmental and socially responsible projects (UNEP, 2020; IFC, 2022). Furthermore, technology-driven solutions, such as fintech innovations, can play a pivotal role in enhancing the efficiency and accessibility of sustainable finance (UNESCAP, 2022; World Bank, 2021). These technological advancements can facilitate financial inclusion and promote sustainable investments in previously underserved areas.

Impact measurement and reporting will also gain prominence as stakeholders increasingly seek to assess the tangible outcomes of sustainable finance initiatives (GRI, 2021; UNEP FI, 2021). Accurate and transparent reporting will help build trust among investors and consumers, fostering greater participation in sustainable finance efforts.

Additionally, the integration of ESG factors into investment decisions will become more widespread, aligning financial interests with broader sustainability goals (ADB, 2020; GRI, 2021). As investors recognize the long-term value of environmentally and socially responsible investments, sustainable finance will become a mainstream practice.

In conclusion, by embracing the recommendations and trends outlined in this study, stakeholders in Asia and Africa, and beyond, can drive positive change, mobilize investments, and build a more sustainable future for all (UNDP, 2020; UNESCAP, 2022). Collaborative efforts, guided by clear regulatory frameworks, sustainable practices, and capacity building, will pave the way for transformative sustainable finance initiatives (IUCN, 2021; UNEP, 2020). Together, Asia and Africa, as well as the global community, can navigate the challenges of sustainable development and embrace the opportunities for a more sustainable and inclusive world.

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Authors contributions:

1. Abdulgaffar Muhammad is the corresponding author of the article and bears primary responsibility for overseeing the entire theoretical research, concept development, and communication with the journal.
2. Taiwo Ibitomi contributed significantly to the theoretical framework and literature review, providing valuable insights into sustainable finance in Asia and Africa.
3. Dada Durotimi Amos played a crucial role in structuring the theoretical analysis and contributing to the discussions on the impact, efficacy, and prospects of sustainable finance initiatives.
4. Mohammed Bello Idris provided expertise in financial regulations and policies, contributing to the exploration of regulatory frameworks in both regions.
5. Aisha Ahmad Ishaq contributed to the theoretical discussions on financial innovation, capacity building, and best practices for advancing sustainable development.

Overall, this theoretical work on a comparative analysis of sustainable finance initiatives in Asia and Africa was led by the corresponding author, Abdulgaffar Muhammad, who took primary responsibility for the research. The co-authors provided valuable contributions to different aspects of the theoretical analysis, including the theoretical framework, literature review, impact assessment, regulatory analysis, and discussions on financial innovation and capacity building. The collaborative effort of the authors has resulted in a comprehensive study that informs prudent strategies and best practices for advancing global sustainability through sustainable finance.

Data availability: As this research paper is primarily theoretical in nature, it does not rely on empirical data analysis. Instead, it draws upon existing literature, regulatory documents, financial reports, and other relevant sources to conduct a comparative analysis of sustainable finance initiatives in Asia and Africa. The study focuses on theoretical frameworks, conceptual models, and case studies to explore the impact, efficacy, and prospects of sustainable finance in the two regions.

As a result, the concept of data availability in the traditional sense, involving datasets and statistical analysis, is not applicable to this theoretical work. The research heavily relies on publicly available information, academic publications, and expert insights to support its arguments and conclusions.

It is essential to note that theoretical research, like this one, plays a crucial role in advancing knowledge and understanding in various fields. By synthesizing and analyzing existing information, the authors can present a comprehensive and informed perspective on the topic without the need for original data collection. The absence of empirical data does not undermine the significance of the study, as it provides valuable insights and recommendations for advancing sustainable finance initiatives in both Asia and Africa.

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RESEARCH ARTICLE

Towards a sustainable green policing: A Delphi-based forecast of sustainability indicators for law enforcers

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Abstract

The environment holds a vital position within the framework of sustainable development, serving as the foundation upon which social and economic progress relies. However, its vulnerability and the market failures resulting from its degradation pose significant challenges to achieving sustainability. This study was conducted to gain valuable insights into the present and future performance of police officers concerning their role in advancing environmental sustainability. As a result of the consensus among the experts, a total of thirty (30) forecasted sustainability indicators for Green Policing were generated. These indicators represent the combined perspectives and agreements of the experts regarding the essential elements and factors involved in the implementation of Green Policing practices. The indicators are categorized into four themes that emerged from the analysis: Green Police Operations, Green Behavior and Awareness, Environmental Law Enforcement, and Community Partnerships and Engagement. These themes provide a comprehensive framework for guiding and assessing the implementation of Green Policing initiatives in various contexts. In light of these findings, it is strongly recommended that law enforcement agencies operating in the SOCCSKSARGEN region integrate these identified sustainability indicators into their Green Policing strategies and operations. By doing so, they can effectively align their practices with the principles of environmental sustainability and contribute to the overall advancement of Green Policing initiatives. Recognizing the interdependencies and taking concerted actions to address these issues, societies, with the law enforcers as stewards, can pave the way for a more resilient and harmonious relationship with the environment, fostering a sustainable future for generations to come.

Keywords: green police operations; green behavior and awareness; environmental law enforcement; community partnerships and engagement

Introduction

The environment serves as a fundamental pillar of sustainable development, playing a pivotal role in supporting and influencing the social and economic dimensions. Over time, societies have recognized the significance of maintaining a harmonious relationship with the environment to ensure a balanced and sustainable way of life (Mensah, 2019). However, the environment faces continuous pressures and threats, making it highly vulnerable and prone to deterioration. In fact, it has become a prominent source of market failures worldwide, as its degradation undermines the well-being of individuals and societies at large.

The interdependence between the environment and other dimensions of sustainable development is evident. Social and economic progress relies heavily on the availability of natural resources, the functioning of ecosystems, and the stability of ecological processes Chapin III et al., (2009); Harris & Roach (2013). From providing essential resources and ecosystem services to supporting livelihoods and economic activities, the environment acts as a foundation for human well-being and development.

Nevertheless, the relentless exploitation of natural resources, pollution, habitat destruction, climate change, and other anthropogenic factors have severely impacted the environment. These pressures have led to various market failures, where the true value and costs associated with environmental degradation are not adequately accounted for UNEPIRP, 2011). As a result, society faces adverse consequences, such as resource depletion, biodiversity loss, environmental disasters, health risks, and socio-economic imbalances.

Recognizing the fragility and importance of the environment is crucial for addressing these challenges. Efforts must be directed towards sustainable practices, policies, and initiatives that aim to conserve and restore the environment while promoting socio-economic well-being. This necessitates a shift in mindset and behavior, as well as the adoption of innovative approaches that embrace the principles of sustainability, including conservation, resource efficiency, pollution prevention, and climate resilience. By acknowledging the integral role of the environment and addressing the market failures associated with its degradation, societies can strive towards a more sustainable future (Dean & McMullen, 2007). This entails promoting responsible consumption and production patterns, investing in renewable energy and green technologies, preserving ecosystems and biodiversity, implementing effective environmental regulations, fostering public awareness and participation, and encouraging collaboration between stakeholders at local, national, and global levels.

Environmental law enforcement plays a crucial role in driving the pursuit of environmental, social, and economic sustainability. Within this context, the public safety sector holds significant responsibility for enforcing environmental laws and policies, thereby contributing to the establishment of green communities. Recognizing the importance of this role, the present study aimed to forecast the sustainability indicators of police officers in the field of Green Policing (Konyk, 2018; Romualdo 2022).

By focusing on Green Policing, the study sought to understand and predict the extent to which police officers contribute to sustainable practices and outcomes. Green Policing entails the integration of environmental considerations into law enforcement practices, encompassing initiatives such as promoting environmental awareness, enforcing environmental regulations, fostering community engagement, and implementing sustainable approaches within police operations.

Through forecasting the Green Policing sustainability indicators, the study aimed to provide insights into the current and future performance of police officers in terms of their contributions to environmental sustainability. This forecasting process involved analyzing various factors, such as the level of green behavior and awareness among police officers, the degree of environmental law enforcement, the level of community partnership and engagement, and other relevant dimensions identified within the Green Policing framework.

Ultimately, the study aimed to contribute to the advancement of Green Policing as a holistic approach within the public safety sector, integrating environmental considerations into law enforcement practices. By forecasting the sustainability indicators of police officers, the research aimed to provide valuable insights and recommendations to support the ongoing efforts towards creating environmentally, socially, and economically sustainable communities.

Methodology

This study utilized a qualitative research design to gather and analyze data. The research approach involved conducting a thorough literature review to examine existing knowledge and insights on the subject of interest. This review helped establish a foundation for the study and identify key themes, concepts, and theories relevant to the research topic.

In addition to the literature review, the study also employed the Delphi technique as a panel review method. The Delphi technique is a structured communication process that seeks to gather expert opinions and insights on a particular topic. It involves multiple rounds of surveys or questionnaires administered to a panel of experts in the field (Hsu, & Sandford 2007). Through these iterative rounds, the experts provide their perspectives, rate the importance or relevance of specific factors, and share their expert opinions.

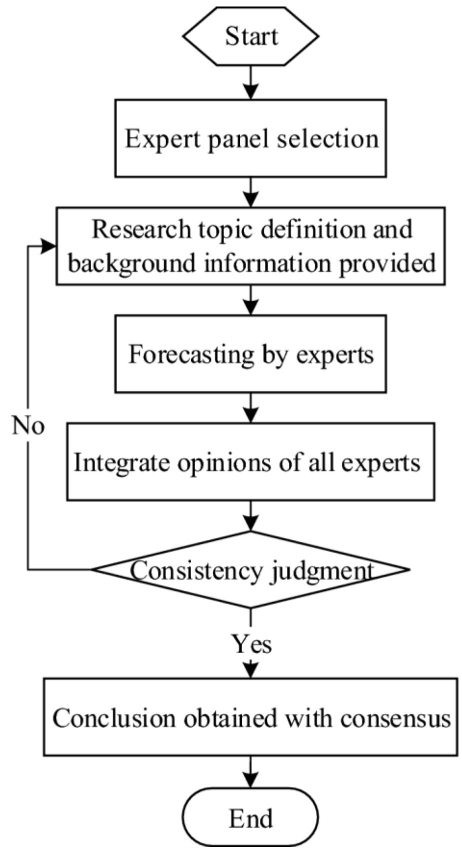

Figure 1. Delphi Processes by Zhang et al., (2022)

The sustainability indicators related to green policing were forecasted based on a constructed scenario and were subsequently validated through a Delphi approach involving a panel of environmental experts. The panel consisted of twelve (12) participants, including five Station Commanders, two Police Section Chiefs, two Coast Guard Commanders, and three Section Chiefs from the Department of Environment and Natural Resources in SOCCSKSARGEN.

Results and Discussion

In the initial round of data collection, a significant number of item responses were obtained from the selected group of experts, amounting to a total of 109 (Figure 2). These responses were carefully transcribed and analyzed to identify key trends and patterns related to green policing. Through a process of coding, the responses were organized and categorized based on their relevance to the overarching themes and concepts of green policing. This restructuring of the data was done to ensure coherence and congruency in the analysis and interpretation of the findings.

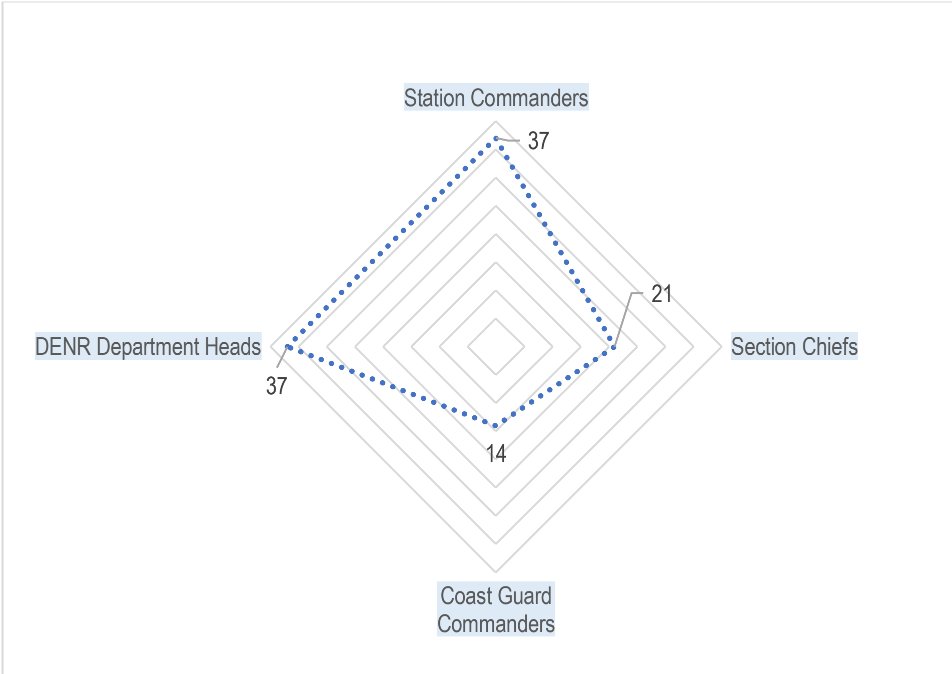

Figure 2. Radar Chart of the Responses of Experts

By transcribing and coding the item responses, common themes, recurring patterns, and important insights regarding green policing were determined. This process allowed for a comprehensive understanding of the expert opinions and perspectives on the topic. The large number of item responses generated in the first round of data collection signifies the richness and depth of the experts' input. It demonstrates the thoroughness and comprehensiveness of the study in capturing diverse perspectives and insights related to green policing.

During the subsequent round of the study (Round 2), the experts were presented with the restructured responses for further review and analysis. The facilitator's objective was to extract more precise and detailed indicators from the experts' initial responses, refining the understanding of the key themes and patterns identified in the data. Out of the original 109 responses, a subset of forty-five (45) responses was selected for further examination and consideration. These refined responses would contribute to a more focused and comprehensive understanding of the indicators associated with green policing. Through the careful transcription, coding, and restructuring of the responses as seen in Figure 3, the researchers were able to extract valuable information and lay the foundation for further analysis and interpretation through codes.

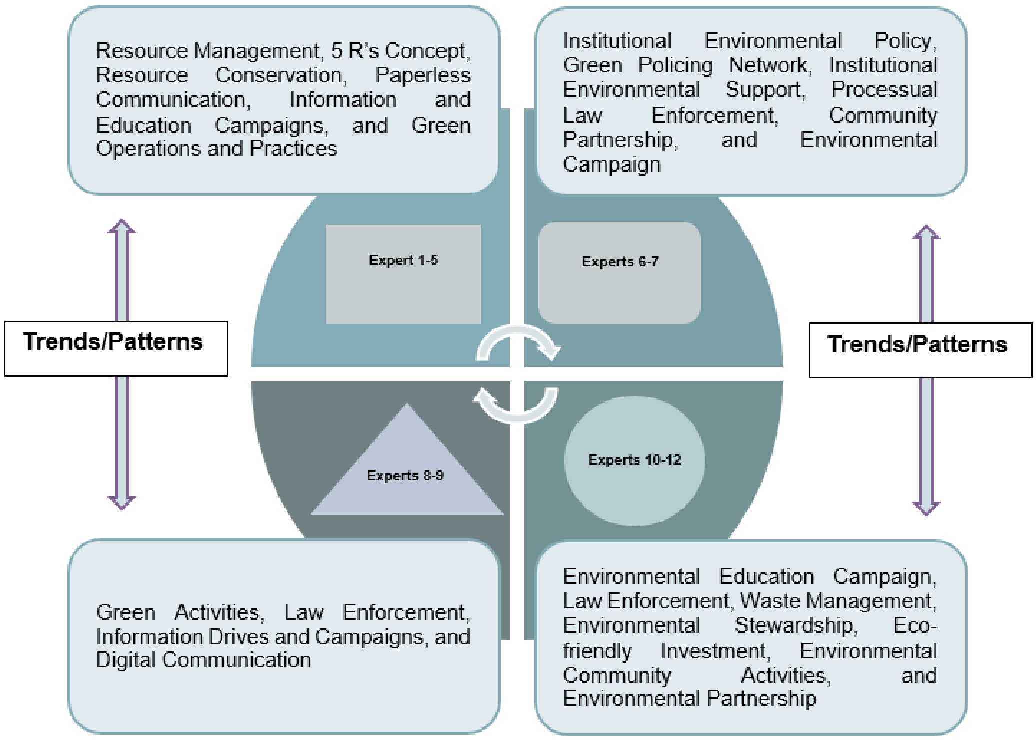

Figure 3. Patterns, Trends, and Indicators in Round 2 of Delphi

After conducting a meticulous examination and comprehensive review of the responses provided by the experts, a total of thirty-five (35) indicators were identified as relevant indicators of Green Policing. These indicators were carefully transcribed by the researcher and further categorized into distinct themes based on the observed trends and patterns within the data. The resulting themes associated with the indicators are as follows: Green Police Operations, Green Behavior and Awareness, Environmental Law Enforcement, and Community Partnerships and Engagement. This categorization allows for a clearer understanding of the different aspects and dimensions encompassed by the concept of Green Policing.

Figure 4. Themes of Sustainable Green Policing

During the final round (Round 3), the experts were engaged in a more focused and constructive manner, leading to the generation of concise and succinct responses. This iterative process aimed to involve the experts in the decision-making process, allowing them to actively participate in the analysis and design of the final research instrument. By incorporating the expertise and insights of the experts, the researcher sought to enhance the instrument's effectiveness and relevance. This approach aligns with the principles outlined by Keeney et al. (2011), emphasizing the importance of engaging experts in the decision-making process to ensure a comprehensive and well-informed outcome.

In the final round, which marked final round, consensus was achieved among the experts. Through a process of discussion and deliberation, a state of homogeneity and consistency in their responses was attained, as highlighted by Graham et al. (2003). This collective agreement among the experts led to the generation of thirty (30) forecasted sustainability indicators of Green Policing. These forecasted indicators represent the shared perspectives and expert consensus on the key aspects and considerations of implementing Green Policing practices (Romualdo, 2022).

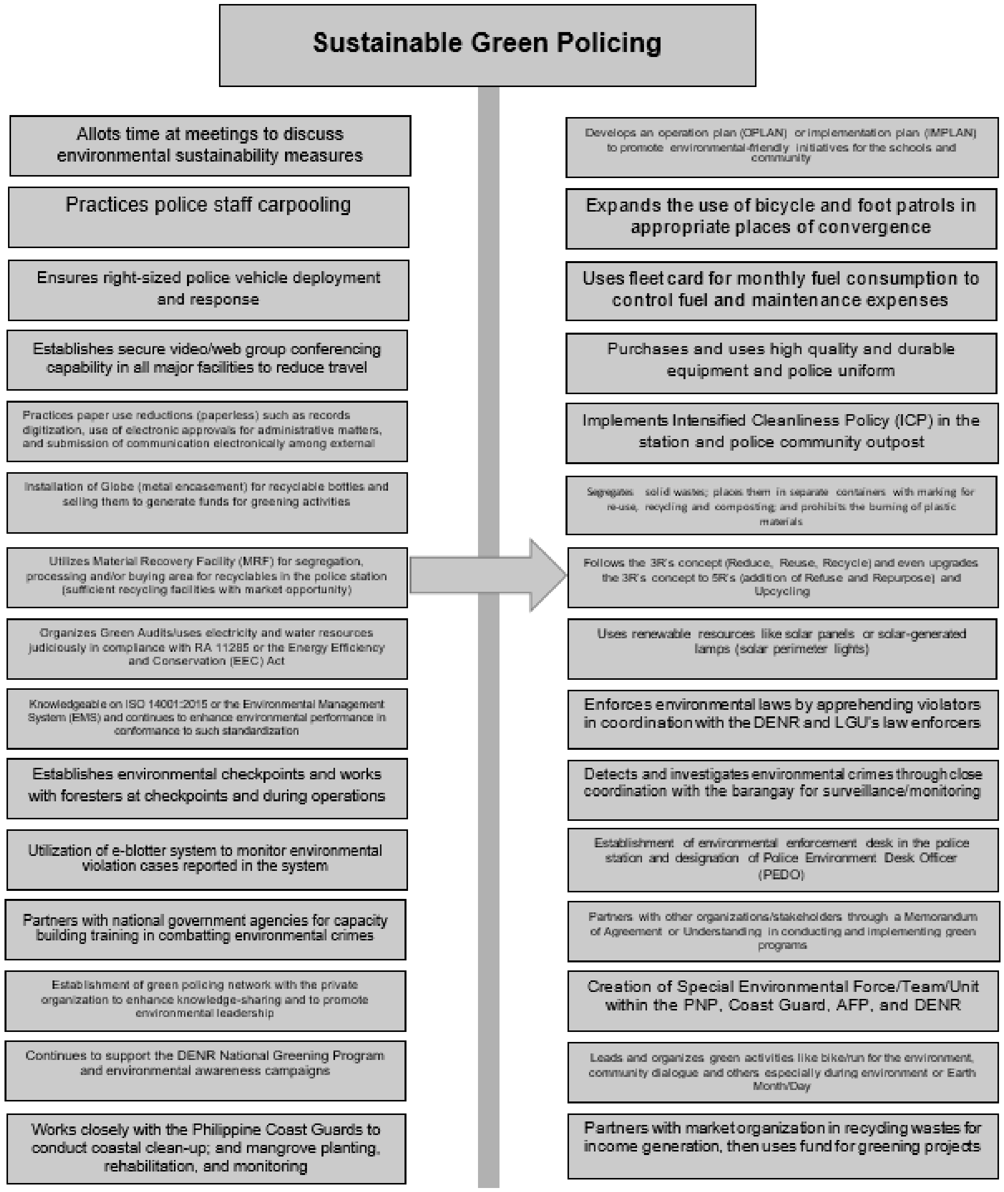

Figure 5. Forecasted Sustainability Indicators of Green Policing

Conclusion and Recommendation

The findings of this study have identified a comprehensive set of sustainability indicators for Green Policing in the SOCCSKSARGEN region. These forecasted indicators reflect the measures and initiatives that police officers can undertake to promote environmental sustainability within their operations and communities. The Green Policing sustainability indicators encompass various aspects such as resource conservation, waste management, renewable energy utilization, collaboration with stakeholders, environmental law enforcement, and community engagement.

Based on these findings, it is recommended that law enforcement agencies in the SOCCSKSARGEN region incorporate these sustainability indicators into their Green Policing strategies. This can be achieved through the development and implementation of specific policies, guidelines, and training programs that align with the identified indicators. Additionally, close collaboration with relevant agencies, organizations, and stakeholders should be fostered to ensure the effective implementation of these initiatives.

Furthermore, regular monitoring and evaluation of the progress made in implementing the sustainability indicators are crucial to assess the effectiveness of Green Policing efforts. This will help identify areas for improvement, refine strategies, and ensure the long-term sustainability of environmental initiatives within the public safety sector.

Public awareness campaigns and community engagement activities should also be prioritized to promote a culture of environmental responsibility among both police officers and the wider community. Partnerships with organizations such as the Philippine Coast Guard and market organizations can be established to facilitate recycling programs and income-generating activities that contribute to environmental sustainability.

By adopting and implementing these sustainability indicators of Green Policing, police officers in SOCCSKSARGEN can pave the way for fostering greener and safer communities, thus contributing significantly to forging a sustainable future.

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Contribution/Originality: This research contributes to the breadth of knowledge by providing a forecast of the indicators of environmental sustainability in public safety through a Delphi technique. As an outcome of this independent and original work, we duly acknowledge all the sources from which the ideas have been derived.

Declaration of Conflicting Interest. The authors declare no conflicts of interest in the development of this research work.

Availability of Data: The authors confirm that the data supporting the findings of this study are available within the article and its Supplementary material. Raw data that support the findings of this study are available from the corresponding author, upon reasonable request.

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REVIEW ARTICLE

Transforming Pakistan's Agriculture Sector through Fintech: Opportunities for Financial Inclusion and Sustainable Development

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Abstract

This study investigates how fintech solutions can increase financial inclusion for smallholder farmers and other stakeholders in Pakistan's agriculture sector. Using a thematic literature review, the study identifies effective and sustainable fintech solutions and explores the challenges and opportunities for scaling up these solutions. The study found that digital platforms for loans, payments, and market linkages have the potential to provide farmers with greater access to finance and other financial services. To promote financial inclusion, the study recommends that policymakers, investors, and fintech startups prioritize the development of fintech solutions that address the specific needs of smallholder farmers and other underserved communities. These solutions should be designed to promote trust and transparency to ensure their long-term sustainability. The study also calls for greater collaboration between the fintech and agriculture sectors to develop innovative solutions and promote financial inclusion in Pakistan's agriculture sector. The findings of this study have important implications for promoting financial inclusion in Pakistan's agriculture sector, which is a vital contributor to the country's economy. The study provides valuable insights for policymakers, investors, and fintech startups who are interested in leveraging fintech solutions to transform the sector and promote financial access and empowerment for underserved communities.

Keywords: Agri-fintech; financial inclusion; smallholder farmers; agriculture in Pakistan; sustainable development

Introduction

The emergence of Financial Technology (FinTech) and the digital economy has garnered significant interest from businesses, academia, and various public and private entities. FinTech represents a pivotal concept and implementation that have stimulated research across diverse disciplines, including agriculture and farming. In the pursuit of sustainability and enhanced productivity, smart connectivity plays a vital role, facilitated by the digital marketplace. This platform enables novel forms of communication and transactions among the numerous stakeholders engaged in agricultural operations, encompassing consumers, suppliers, farmers, investors, distributors, and others involved in the agricultural business landscape (Anshari et al., 2019).

Agriculture, primarily in developing nations, faces difficulties with typical business processes due to cash shortages, capital problems, restricted access to financial institutions, and a lack of market access. The supply chains in agriculture have numerous layers, from farmers to consumers, adding to the cost of the product (Anshari & Alas, 2015). A digital marketplace that supports FinTech could improve agriculture. Demand shifts will be hastened by the digital market, which will increase consumer interest in foods from various regions. As a result, incorporating FinTech into the digital marketplace might solve the regular problems with farmers' finances and encourage the public to participate in agriculture (Anshari & Lim, 2017).

Moreover, financial inclusion has emerged as a critical factor in promoting sustainable economic growth and reducing poverty, particularly in developing countries like Pakistan (Demirgüç-Kunt et al., 2018). The agriculture sector, which plays a pivotal role in Pakistan's economy, is largely characterized by smallholder farmers, who often face significant barriers to accessing formal financial services (World Bank, 2019). This paper seeks to explore the potential of fintech solutions to increase financial inclusion for these smallholder farmers and other stakeholders in Pakistan's agriculture sector.

In pursuit of the research objective, a thematic literature review methodology was implemented. The current study delves into the identification of effective and sustainable fintech solutions as well as the challenges and opportunities for scaling up these innovations (Creswell et al., 2017). The research sheds light on the transformative potential of digital platforms for loans, payments, and market linkages in increasing access to finance and other financial services for farmers (Buku & Meredith, 2018).

Literature Review

The literature on financial inclusion and the role of fintech in promoting access to financial services for smallholder farmers has grown substantially in recent years. This literature review aims to synthesize the current body of knowledge on the potential of fintech solutions to foster financial inclusion for smallholder farmers and other underserved communities, particularly in the context of Pakistan's agriculture sector. By examining the barriers faced by smallholder farmers in accessing formal financial services, the emergence of fintech solutions, the importance of trust and transparency, and the need for collaboration between the fintech and agriculture sectors, this review provides a comprehensive understanding of the challenges and opportunities for leveraging fintech to enhance financial inclusion in the agriculture sector.

Financial Inclusion and Smallholder Farmers

Financial inclusion, the process of ensuring access to and usage of formal financial services by all individuals and businesses, has been widely acknowledged as a crucial factor in reducing poverty, promoting sustainable economic growth, and enhancing overall wellbeing (Demirgüç-Kunt et al., 2018; Karlan et al., 2016; CGAP, 2020). The significance of financial inclusion is particularly notable for smallholder farmers in developing countries like Pakistan, who often face considerable barriers to accessing formal financial services, including savings, credit, insurance, and payment systems (World Bank, 2019; IFAD, 2019).

Smallholder farmers are a critical population, representing the majority of the agriculture sector and contributing to food security and poverty reduction (FAO, 2017; AGRA, 2020). They play an essential role in ensuring the resilience of rural communities and maintaining the stability of local food systems (Lowder, Skoet, & Raney, 2016). However, limited access to credit, insurance, and other financial services inhibits their productivity and growth potential (Pakistan Bureau of Statistics, 2021; Cole, Sampson, & Zia, 2011). Access to financial services is critical for smallholder farmers to invest in productivity-enhancing inputs, manage risks associated with weather and market fluctuations, and access new markets for their products (Wiggins, Keats, & Han, 2016).

Factors such as lack of collateral, low financial literacy, and the absence of a credit history further exacerbate these challenges (Banerjee & Duflo, 2011; Beck, Demirgüç-Kunt, & Martinez Peria, 2007). Additionally, the high transaction costs associated with serving smallholder farmers in remote rural areas often discourage formal financial institutions from extending their services to this population (Gash & Odell, 2013). This results in a significant proportion of smallholder farmers relying on informal sources of finance, such as borrowing from friends, family, or moneylenders, which often entail high interest rates and limited protection mechanisms (Hermes & Lensink, 2007; Guérin, Labie, & Servet, 2015).

The promotion of financial inclusion for smallholder farmers has thus become a significant policy objective for governments, development organizations, and the private sector (UN, 2015; G20, 2017). Numerous studies have demonstrated the potential benefits of financial inclusion for smallholder farmers, including increased investment in agricultural inputs, improved productivity, higher income levels, and reduced vulnerability to shocks (Kaboski & Townsend, 2011; Karlan, Osei, Osei-Akoto, & Udry, 2014). As such, understanding the barriers to financial inclusion faced by smallholder farmers and identifying effective strategies to overcome these obstacles is crucial for promoting sustainable development and poverty reduction in rural areas (Brune et al., 2016; Awotide, Karimov, & Diagne, 2016).

Fintech Solutions for Financial Inclusion

The emergence of financial technology (fintech) has opened new avenues for promoting financial inclusion among smallholder farmers and other underserved communities (Alliance for Financial Inclusion, 2016). Fintech solutions such as digital payments, mobile banking, and peer-to-peer lending platforms have demonstrated the potential to increase access to financial services and improve financial management for marginalized populations (Buku & Meredith, 2018). These innovative solutions also address barriers related to physical distance, cost, and complex documentation, which are often cited as reasons for financial exclusion (Demirgüç-Kunt et al., 2018).

Trust and Transparency in Fintech Solutions

The success of fintech solutions in promoting financial inclusion largely depends on their ability to foster trust and transparency among users (M-Pesa, 2020). Trust is a critical factor in the adoption and usage of digital financial services, particularly for individuals who have limited experience with formal financial institutions (Buku & Meredith, 2018). Transparency, on the other hand, is essential for building confidence in these services and ensuring that they adhere to regulatory requirements and consumer protection standards (Alliance for Financial Inclusion, 2016).

Collaboration between Fintech and Agriculture Sectors

The integration of fintech solutions into the agriculture sector necessitates increased collaboration between the two sectors to develop innovative and context-specific solutions (FAO, 2017). This collaboration can lead to the development of tailored products and services that address the unique financial needs of smallholder farmers, such as weather-based insurance, digital credit services, and market linkages (World Bank, 2019). Such targeted solutions can contribute to greater financial inclusion, enabling smallholder farmers to enhance their productivity, manage risks, and access new markets (UNCTAD, 2018).

The literature highlights the potential of fintech solutions to promote financial inclusion for smallholder farmers in developing countries like Pakistan. The integration of digital platforms for loans, payments, and market linkages can provide farmers with increased access to finance and other financial services. Trust and transparency are key factors in the success and sustainability of these solutions, and greater collaboration between the fintech and agriculture sectors is necessary to develop innovative solutions tailored to the specific needs of smallholder farmers.

The present study is structured into distinct sections aimed at facilitating a systematic exploration of financial inclusion within the agricultural sector. The introduction section demonstrates an overview of financial technology, emphasizing its critical role in strengthening the agricultural ecosystem in Pakistan. The methodology section delineates the research design employed, which involved a meticulous selection of relevant thematic literature review documents. The results section presents the outcomes obtained from comprehensive data analysis conducted within the framework of this research endeavor. Lastly, the conclusion section provides a concise summary of the key findings and their implications. Additionally, the study acknowledges its limitations and proposes recommendations for future research endeavors.

Methodology

A systematic literature review is a “rigorous, explicit, and transparent method”. For the current study, a thematic literature review was employed. In a thematic literature review, the writer arranges and analyzes previously published research studies in accordance with themes or conceptual frameworks that, in the writer's view, are crucial to comprehending the subject. For the current study, three themes were established to structure the literature review i.e. access to financial technology, awareness of financial technology, and financial support.

To conduct the comprehensive review, a targeted selection of keywords was utilized to develop an outline for the collection of relevant publications that formed the basis of the present review. Prominent scholarly databases, including Google Scholar, Crossref, and Scopus, were employed as primary resource engines. Consequently, this thematic systematic review encompasses the entirety of the data identified through a meticulous search across the aforementioned databases. These databases were chosen due to their extensive coverage of findings derived from the initial scoping search. By employing the specified keywords, all publications incorporating finance, financial inclusion, agriculture, smallholder farmers, agriculture in Pakistan, and fintech-agriculture in the abstracts, titles, and keywords were identified.

To ascertain the inclusion or exclusion of studies in the final dataset, a thorough examination of the abstracts was conducted, and in cases where categorization was uncertain, the entire texts were scrutinized. The primary criterion for inclusion or exclusion was the presence of a clear connection between agriculture and finance. This evaluation enabled the identification of a substantial volume of pertinent research; however, it necessitated the exclusion of some significant and captivating research publications. Notably, certain previously identified relevant results from a preliminary scoping search were deemed hesitant for incorporation due to the lack of transparency in its search mechanism, thus hindering easy replication.

Table:1

S. No	Title of Research paper	Author (s)	Year	Key Findings
		Access to Financial Technology		
1.	Role of ICT & Fintech in Indian Agriculture	More & Aslekar	2022	Smallholder farmers and other rural firms can greatly benefit from having access to digital technology since it allows them to obtain support, create strategic partnerships, and access training, and financial, and legal services.
2.	A Proposed Shariah-Compliant Fintech Model as An Alternative Financing Product to Tackle Food Security Challenges in Malaysia	Azganin, et al.,	2021	This study offers a comprehensive shariah investment procedure and structures of the fintech industry, which can assist policymakers to create necessary policies that regulate Crowdfunding and smart contracts activities.
3.	DIGITAL PLATFORMS IN THE NEW WORLD OF DIGITAL AGRICULTURAL BUSINESS	Kolmykova, et al.,	2021	This strategy for the agricultural sector's digital transformation will help to qualitatively restructure all organizational and production operations, which will eventually lay the groundwork for improving efficiency and lowering risk across the whole agricultural industry.

4.	FINTECH AND DIGITAL MARKETPLACE: TURNING MINDFULNESS ACTIVITIES OF ASIAN COUNTRIES	SUMITHRA	2023	The FinTech era occurs to strengthening, advances horticultural opportunities in rural areas, extraordinary levels of creation in industrialization, and contributes to maintainability, public pay, and neediness reversal.
5.	CHALLENGES AND OPPORTUNITIES IN EMPLOYING THE FINANCIAL TECHNOLOGIES BY PACS IN INDIA- A SWOT ANALYSIS	Naithani, et al.,	2022	fintech will help them not only expand their products and membership base but also ease the targeted distribution of services by the government with E-rupi being the latest addition
6.	Examining how digital marketplace adoption and fintech adoption contribute to the sustainability of selected small agribusinesses in Metro Manila: A multiple case study approach	Chan, et al.,	2022	Adoption of digital marketplace and FinTech contributed to the overall agribusiness sustainability
7.	Fin- Tech in Indian Agricultural Sector	Kanagavalli, et al.,	2021	The digitalization of agriculture will cause a significant shift in farming and food production over the coming years
8.	The effects of financial inclusion on agricultural productivity in Nigeria	Fowowe	2020	financial inclusion, irrespective of how it is measured, has exerted positive and statistically significant effects on agricultural productivity.
9.	Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges	Birner, et al.,	2021	Digital agriculture technology has the potential to create an agricultural revolution, making crop and livestock production more efficient and more environmentally friendly and contributing to higher productivity.
10.	Digitalization of Agri-Cooperatives in the Smart Agriculture Context. Proposal of a Digital Diagnosis Tool	Ciruela-Lorenzo, et al.,	2020	The digitalization process based on smart technologies (IoT, robots, AI, BD, and Blockchain) is transforming the agricultural sector and promoting sustainability in different ways.

		Awareness of Financial Technology		
11.	Fintech and crowdfunding as tools for financing the reproduction process in agricultural activities	Eskiev	2021	The digital marketplace concept of crowdfunding brings together every participant (farmers, landowners, investors, and consumers) in a space that can foster openness, empowerment, resourcefulness, and community involvement in agriculture.
12.	Fintech in sub-Saharan Africa	Ndung'u	2022	fourth Industrial Revolution, driven by fintech, has the potential to propel the continent to higher levels of savings, investments, employment, and inclusive growth, provided an appropriate legal and regulatory framework is put in place
13.	Review and analysis of FinTech approaches for smart agriculture in one place	Pothula	2023	FinTech could promote agricultural sustainability. The financial sector is critical in allowing agriculture to contribute to economic growth and poverty reduction.
14.	Emergence of Agri Fintech for Inclusive Growth	Kumar	2021	The development of technology has had a significant impact on the adoption of better farming practices that utilize fewer resources while producing more.
15.	The Role of Finance in Navigating Agriculture through Agri-FinTech	Pothula	2022	Agri-FinTech can only benefit if they recognize this potential and embrace it properly
16.	Sustaining Performance of Wheat–Rice Farms in Pakistan: The Effects of Financial Literacy and Financial Inclusion	Raza, et al.,	2023	Increased trust in financial services is essential for improving sustainable performance in the agricultural sector.

17.	Machine Learning Applications for Precision Agriculture: A Comprehensive Review	Sharma, et al.,	2020	Precision agriculture is empowering the farmers with technology intending to get optimum outputs with precise inputs. IoT-enabled smart sensors, actuators, satellite images, robots, and drones are some of the key technological revolutions that boosted the agriculture industry.
18.	Making Smallholder Value Chain Partnerships Inclusive: Exploring Digital Farm Monitoring through Farmer-Friendly Smartphone Platforms	Agyekumhene, et al.,	2020	Co-designing a platform interface was significant in improving farmer ability to comprehend and use smartphone-based platforms for communicating farm conditions and their needs with value chain partners.
		Financial Assistance		
19.	Does FinTech credit scale stimulate financial institutions to increase the proportion of agricultural loans?	Mohsin, et al.,	2022	The FinTech Credit scale can raise the proportion of loans for agriculture in financial institutions.
20.	Islamic P2P Crowdfunding (IP2PC) Platform for the Development of Paddy Industry in Malaysia: An Operational Perspective	Azganin, et al.,	2021	Paddy farmers in Malaysia will have access to an alternate means of funding through Islamic P2P crowdfunding, which will help them fulfill their financial needs and fund their small businesses.
21.	Proposed waqf crowdfunding models for small farmers and the required parameters for their application	Azganin, et al.,	2021	With the help of the proposed crowdfunding, poor farmers would be able to meet their needs and contribute to the economic growth of their nation.
22.	Use of Financial Technology for Agricultural Financing Through Islamic Financial Institutions	Maryam & AHAMAD	2021	Financial technology with value chain financing emerged as a viable alternative that can tackle financing issues by integrating small farmers and other stakeholders with IFIs.

23.	Financing Sustainable Agriculture in Sub-Saharan Africa: A Review of the Role of Financial Technologies	Mapanje, et al.,	2023	The technologies can help to increase the effectiveness of financing smallholder agriculture and more people will be able to embrace sustainable agricultural practices.
24.	A STUDY ON FIN- TECH IN INDIAN AGRICULTURAL SECTOR	Reddy, et al.,	2020	Farmers are facing financial problems in the agricultural sector. With the help of Fintech financial problems can reduce by providing credit facilities to farmers
25.	The Role of Islamic Crowd Investing for Sustainable Agriculture in Indonesia	Sari & Kassim	2021	Financial technology, such as Islamic crowd-investing has an important role not only in terms of funding but also in achieving sustainable agriculture.
26.	Can digital financial inclusion effectively stimulate technological Innovation of agricultural enterprises? A case study on China	Zhu & Li	2021	Digital financial inclusion plays a significant role in promoting the technological innovation efficiency of agricultural enterprises.
27.	Does Digital Finance Increase Relatively Large-Scale Farmers' Agricultural Income through the Allocation of Production Factors? Evidence from China	Song, et al.,	2022	Digital finance has a substantial positive influence on relatively large-scale farmers' agricultural income.

Findings

In the current research study, a comprehensive thematic literature review was done to investigate the transformation of Pakistan's agriculture sector through fintech and opportunities for financial inclusion and sustainable development. The overview examines the possible changes and opportunities for Pakistan's agriculture. The study also intended to understand how the use of fintech would impact and improve smallholder farmers as a whole and significant shift in agriculture.

According to the findings, the emergence and widespread implementation of fintech might result in a number of significant effects on agriculture productivity. The review's findings indicate that fintech might have a huge impact and can foster openness, empowerment, resourcefulness, and community involvement in agriculture.

The comprehensive literature review provides valuable insights into the potential effects of the emergence and widespread adoption of fintech. The collective findings from these studies indicate that fintech has the capacity to positively impact the agricultural sector. Research suggests that digital agriculture technology holds the potential to catalyze an agricultural revolution by enhancing the efficiency and environmental sustainability of crop and livestock production, ultimately contributing to increased productivity. As the digitalization of agriculture continues to gain momentum, significant shifts in farming practices and food production are expected in the coming years.

Fintech, including the recent addition of E-rupi, not only enables agricultural entities to expand their product offerings and customer base but also facilitates the targeted distribution of government services. Additionally, the ongoing digitalization process, driven by intelligent technologies such as the Internet of Things (IoT), robotics, artificial intelligence (AI), big data (BD), and blockchain, is profoundly transforming the agricultural sector and promoting sustainability in various ways. Precision agriculture, for instance, empowers farmers by leveraging technology to achieve optimal outputs with precise inputs. IoT-enabled smart sensors, actuators, satellite imagery, robots, and drones are among the key technological advancements that have revolutionized the agriculture industry.

As long as financial assistance is concerned, the utilization of FinTech credit platforms has the potential to increase the allocation of loans for the agricultural sector within financial institutions. A research study conducted in 2021 revealed that the implementation of crowdfunding mechanisms can enable impoverished farmers to address their financial requirements and contribute to the economic development of their respective countries. It is widely acknowledged that farmers encounter significant financial challenges within the agricultural industry. Through the integration of FinTech solutions, these financial difficulties can be mitigated by offering credit facilities to farmers.

Conclusion

The above-mentioned thematic literature review provides a clear picture that framers will highly benefit from the provision of digital assistance. They will be able to adopt sustainable agricultural practices as a result of the technology's potential to boost the effectiveness of funding smallholder agriculture. Moreover, farmers, landowners, investors, and consumers with digitalization will bring together an environment that can promote openness, empowerment, inventiveness, and involvement of the community in agriculture through the digital marketplace concept of crowdfunding.

The findings of this study hold significant implications for the promotion of financial inclusion in Pakistan's agriculture sector, a cornerstone of the nation's economy (Pakistan Bureau of Statistics, 2021). As a valuable resource for policymakers, investors, and fintech startups, this paper offers insights into harnessing the power of fintech solutions to revolutionize the sector and promote financial access and empowerment for underserved communities (UNCTAD, 2018).

The paper offers recommendations for policymakers, investors, and fintech startups to prioritize the development of solutions tailored to the specific needs of smallholder farmers and other underserved communities (Alliance for Financial Inclusion, 2016). It emphasizes the importance of trust and transparency in the design of these solutions to ensure long-term sustainability (M-Pesa, 2020). Furthermore, the study calls for increased collaboration between the fintech and agriculture sectors to jointly develop innovative solutions that can drive financial inclusion in Pakistan's agriculture sector (FAO, 2017).

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REVIEW ARTICLE

Sustainable Development in Europe: A Review of the Forestry Sector's Social, Environmental, and Economic Dynamics

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Abstract
Despite their resilience, forest ecosystems become increasingly impacted by extreme climatic events, fires, and pathogen outbursts, which have considerable economic repercussions. How forest management solves these difficulties will affect human health, environmental variety, productivity, and forest ecosystem recuperation from exogenic distresses. Assuming forests provide ecosystem services essential to society and humanity along with wood, a better understanding of forest ecosystems seems essential to defining a development policy that meets ecological safeguard and energy and climate goals. According to the UN 2030 Agenda's Sustainable Development Goals, European forest management practices still don't provide a clear picture of ecological conditions, monetary estimate, and biodiversity. In light of the existing research, this article reviews and discusses recent European forestry industry trends and the environmental-economic nexus' complexity. Wood use has social consequences for regions adapting to ecological change, from rising temperatures to landscape modifications. This paper confirms that the technical-economic dimensions of forestry affect short-term economic dynamics, sector growth prospects, supply chain organization, company interconnections, and investment strategies. Forestry practices conserve species and habitats while boosting sustainable timber production. The European Commission's policy direction is to gradually encourage public and private entities to embark on worthy circular economy pathways, which will result in more jobs, material recycling, minimized carbon emissions, and community-added value. Forestry should contribute more holistically to sustainable development at diverse spatial dimensions. This includes focusing on environmental and economic aims in light of the recognition of relevant features that may guide forthcoming research and policy action while enhancing cooperation among member nations and local experts.

Keywords: Forest resources; Wood; Conservation; Circular economy; Sustainability; European Union

Introduction

The European Union's economic resurgence from the Great Recession has not been accompanied by widespread and consistent expansion across the continent. An underlying uncertainty regarding future socioeconomic dynamics is outlined by the possessions of the epidemic catastrophe and, more lately, the geo-political war on the Eastern tip of the region, with corresponding energy issues (Martinho, 2022; Raihan & Tuspekova, 2022a; Zakeri et al., 2022). The potential to shift toward a completely circular economy and an extremely sustainable development pathway is hampered in many cases by this vagueness, which has large but similarly varied implications on the distinct production segments (Raihan & Tuspekova, 2023a; Anghel & Jones, 2023; Raihan et al., 2023a). Even before the pandemic, regional and local markets were mostly responsible for managing these difficulties, often with great effectiveness (Allam et al., 2022; Raihan et al., 2022a; Voumik et al., 2023a). Global and local climate change have made certain supply chains especially vulnerable to ecological, territorial, and community concerns (Nocentini et al., 2017; Ghadge et al., 2020; Raihan & Voumik, 2022a; Raihan et al., 2022b; Isfat &

Raihan, 2022; Voumik et al., 2022; Ghosh et al., 2023; Raihan & Himu, 2023; Sultana et al., 2023; Voumik et al., 2023b) due to their exposure to continuous transformations reflecting the ecological transition (Raihan et al., 2022c).

Simultaneously, it was shown that forest ecosystems are ever more vulnerable to hazards like extreme climatic events, fire, pathological epidemics, and general anthropological actions, all of which have significant (yet poorly quantified) economic impacts (Corona, 2019; Pecchi et al., 2019; Ali et al., 2022; Raihan & Tuspekova, 2023b). How these problems are dealt with by forest management will have far-reaching consequences for human health, biodiversity, productivity (economic and ecological), and the capability of forest ecologies to withstand external distresses (Begum et al., 2020; Raihan & Tuspekova, 2022b; Raihan et al., 2023b). Forests provide numerous ecological services that are important to civilization and social interests (Raihan et al., 2018; Angelstam et al., 2019; Raihan et al., 2018; Doimo et al., 2020; Newton et al., 2020; Raihan et al., 2021a; Raihan et al., 2023c), and not just wood stuff (Raihan et al., 2021b; Raihan & Tuspekova, 2022c; Raihan et al., 2023d). Businesses and society as a whole benefit from a focus on environmental sustainability since it lowers risk, encourages innovation and entrepreneurship, and makes supply chains more competitive (Lazdinis et al., 2019; Aszalós et al., 2022; Raihan & Tuspekova, 2022d; Raihan et al., 2022d). The International Panel on Climate Change (IPCC) has reaffirmed the value of forests and associated prolific segments, showing how CO_2 emissions can be cut by as much as a third using only environmentally friendly methods (Raihan & Tuspekova, 2022e; Raihan & Voumik, 2022a). That's why it's important to support companies and management techniques that strengthen interdependent supply chains and forest ecosystems (Masson-Delmotte et al., 2021; Raihan & Tuspekova, 2022f). Europe's forestry industry serves many purposes, from creating jobs and boosting rural economies to consolidating (at least indirectly) the recreational pleasures associated with mature forests (Corona et al., 2016). Spending time in woods has been shown time and over again to be beneficial for stress reduction, mood elevation, and even health recovery (Grilli & Sacchelli, 2020). Lawbreakers, psychiatric patients, youngsters emotionally troubled, and people with psychological healthiness concerns are just some of the populations who have been the focus of numerous research that have investigated the efficacy of forest-related therapy lineups in improving their condition (Shin et al., 2010; Raihan & Tuspekova, 2022g). Forests play an important role in delivering ecosystem facilities (Raihan & Tuspekova, 2022h), including an extensive array of recreational and tourism events like picnicking, hiking, and biking, and this fact has been widely disseminated thanks to numerous worldwide enterprises, such as the European edges COST act E39. Thus, there has been a push to acknowledge forests' potential as places for recreation, stress reduction, and relaxation (Grilli & Sacchelli, 2020). While forestry has obvious economic benefits, wood also has major manufacturing and energy uses, the latter of which is expected to rise in the current geopolitical context (Zakeri et al., 2022; Skyrman, 2022). Given our nation's rich forest history, this appears to be a beneficial development; but it is also seen negatively because it may reduce demand for wood used in higher-value manufacturing processes. Meanwhile, a structural issue of reliance on foreign supply plagues businesses, particularly furniture industries (Santos et al., 2019; Ghadge et al., 2020). Data from authoritative sources suggests, albeit in a roundabout way, that the inherent vulnerability of forest formations is becoming more apparent and increasingly accompanying with the financial and communal dynamics of confined regions, demonstrating a foundation of instability and ambiguity and diminishing the probable flexibility of whole areas to worldwide changes (MacDicken, 2015). When the adjacent circumstances (accessibility, absorptivity to modernization, networking, trade openness) are unfavorable, doing business can be extremely challenging, especially in economically underprivileged circumstances like national and peripheral zones in the ancient landmass (Bowditch et al., 2020).

The present article draws on a literature analysis to examine the changing face of European forestry and to outline the environmental and economic complexities that define the forest industry. Significant communal insinuations for resident regions familiarizing themselves with ongoing ecological alteration, from global warming to topography modifications, stem from the widespread usage of a significant natural resource like wood (Garbarino et al., 2020; Raihan et al., 2022e). In line with previous research, this review article recommends the significance of the technological-financial attribute of forestry in the sustainable development routes of regions and counties (Hazarika et al., 2019), which influences short-range economic dynamics, sector expansion possibilities, supply chain organization, interconnectedness among corporations, and financing approaches in general. Simultaneously, this review's contribution provides

evidence that simplistic interpretations based on purely ‘technical’ points of view cannot capture the nuances of forestry and its inherent interaction with additional economic segments and ecological challenges. This research, on the other hand, lends credence to the idea that including a ‘holistic’ interpretation of forestry into sustainable development pathways across spatial scales would be beneficial. Only by defining future avenues of theoretical research and empirical examination it might be possible to achieve the social, environmental, and economic goals of forestry that are essential to its success.
This review article is structured as follows to answer the important query of sustainable development in every manufacturing segment with pertinent implications on the environmental quality. In the second section, this article presents a quick look at the shifting landscape of European forests. The consequences of forestry on the natural world are the subject of the third section. The fourth section summarizes authorized statistics and introduces an ephemeral examination of the prolific interconnectedness amid the forestry sector and the furniture manufacturing in Europe, outlining the financial utilization of forest resources besides the supply chain of wood-furniture. The sustainability-focused framework of European forest policy and its most recent developments are summed up in the fifth section. The review article concludes with an exposed discussion of the key questions at play in the debate over forestry’s environmental and economic influence in developed markets, potentially differentiating between central and peripheral locations, where forestry signifies a pertinent added value in country structures that might be better adjusted with the feature of ecological reinforcement.

Recent dynamics in European forest resources

Deforestation is increasing at a degree of yearly 10 million ha (FAO, 2020), while forest area is decreasing at an alarming rate of 4.7 million ha annually on average. Brazil, Congo, Indonesia, Tanzania, Angola, Paraguay, Cambodia, Myanmar, Mozambique, and Bolivia are among the nations with the biggest net (year average) forest cover losses throughout the last decade (FAO, 2020). However, over the last 30 years, there has been a greater recognition of the significance of forest conservation measures, leading to an increase of nearly 200 million hectares of protected forest areas from 1990 to 2020 (FAO, 2020). European Union (EU) land and about 6% of marine zones (encompassing roughly 850,000 km^2) are protected by the Natura 2000 network, one of the newest projects introduced and the biggest coordinated network of protected sites in the EU. This system was developed in response to the Habitats Directive and the Birds Directive with the goals of protecting endangered species in their natural environments and ensuring the continued functioning of ecosystems for future generations (Evans, 2012).
Establishment of forest cover, specifically in peripheral regions of developed nations, is a feature of advanced economies (Pagnutti et al., 2013), which are consistent with trends observed in Europe’s forests. One of the most significant shifts in land use over the past two centuries in Europe was the increase in forest cover, which was spurred on by widespread reforestation efforts. However, the acceleration of technical improvements that intensified the farming systems on reduced ranges is also a result of rural emigration; these changes have freed up land-dwelling for the recolonization of forests, especially on unrestrained and formerly farmed land (Frei et al., 2020; Santarsiero et al., 2023). Western European forest cover grew by over 30 percent in the half-century after WWII (Charru et al., 2017). Central-Eastern and Southern Europe saw slower rates of growth (20% and 16%) compared to Northern Europe, where forests were before now the dominant land covering by the middle of the previous century. Still, forest area has increased practically everywhere up to now, though it has slowed down significantly meanwhile the immediate 1990s. Western Europe is the only region where this trend has reversed. There will be 10.2 million hectares more of forest in Europe by 2020 than there were in 1990. About 45% of the land cover of the European Union (EU) was comprised by forests and woodlands in 2020 (excluding inland seas), making the EU home to about 5 percent of the Earth’s total forest acreage (Forest Europe, 2020). As an illustration of long-term tendencies, less than 0.4% and 0.3% of land conversions in Europe have been accounted for by afforestation and deforestation, respectively, in current ages (Forest Europe, 2020).
Sweden’s forest assets are predicted at 30.3 million hectares in 2020 (Purwestri et al., 2020), making it Europe’s largest forest area. While the only other member state was Finland with a concentration of over 20 million hectares, Spain recorded the second-largest area at 28 million hectares (Palátová et al., 2022). Following closely behind was France, with 18.1 million hectares of forest, followed by Italy and Germany, each with roughly 11 million ha of forest (Cook, 2020). In 2020, half of the territory of the 8 member countries will be covered by forests. Slovenia (62.8%), Finland (76.2%), and Sweden

(74.5%) had the greatest rates in comparison to their respective national areas. Forests cover between 50 and 60 percent of the land in Estonia, Latvia, Spain, Portugal, and Greece, but they cover between 11 and 16 percent in the Netherlands, Ireland, and Denmark, respectively. Only Sweden saw a decline in forest cover between 1990 and 2020 (-0.4%), while three Mediterranean European nations (Italy, Croatia, and Cyprus) saw increases of more than 8% during the same time period (Forest Europe, 2020; Kumar et al., 2021).

The effects of human activity have been profound on the structure and content of European forests. Only 26 percent of wild species and 15 percent of forest ecosystems gain a positive conservation category (EEA, 2015). In addition to sequestering 13 percent of Europe's emissions, housing an overriding portion of terrestrial biodiversity, plus making important contributions to climate change mitigation, it has been predicted that forests eliminate roughly 430 million tons of atmospheric CO2 annually (Nabuurs et al., 2018; Raihan & Said, 2022). In 2050, cities will be home to roughly 84% of Europe's population (Pesaresi et al., 2016), have major effects on air and soil conditions and, by extension, the health of people across Europe, particularly the young and the old. Most ecoregions in Europe can expect an upsurge in temperatures and a decrease in precipitation in the future, and this will occur at a more rapid rate compared to the remainder of the globe due to the impact of an inevitable change in the composition of the Earth's atmosphere. Urban forestation initiatives, which involve an enormous rise in planting to improve the microclimate and quality of air in urban areas by capturing carbon dioxide and protecting the soil coming from the sun and rain, are one of the most common ways of coping with the impacts of global warming on cities (Escobedo et al., 2019; Raihan et al., 2022f). Figure 1 presents the forest dynamics components under European classifications.

Figure 1. Forest dynamics under European classifications (Ivanova et al., 2022).

Vital ecosystem facilities and goods are provided by all urban natural areas, including a wide range of green covers (forests, botanical gardens, urban parks, street tree, plantations, and cemeteries; edifice swathe rejuvenation is a relatively new addition to this list) (Escobedo et al., 2011). These include, but are not limited to, the maintenance of habitat attributes, the control of air, soil, water, and climate, besides the provision of food and water (Raihan et al., 2023e). In addition, urban forests, particularly in developed states, may show a pivotal part in resolving resource struggles as a hallmark of modern globalization (Hayter & Clapp, 2020) that arise from the tension between manufacturing urgencies and environmental and social needs (Whiteman et al., 2015; Raihan et al., 2022g; Raihan et al., 2023f). Finally, no authorized map casing vast spatial levels can be regarded acceptable in directing the issue of forest distribution in Europe (Yousefpour et al., 2018). This question can be answered more precisely with the use of official statistics (such as fine-scale agricultural censuses and geo-spatial statistics from forest inventories) and land-use maps.

Influence of forestry on the environment

Inadequate forest management has the potential to jeopardize or even destroy forest resources and services. Still, forestry practices are a major reason why forest habitats and species are in a poor conservation position (Cutino et al., 2018; Raihan et al., 2022h; Raihan, 2023a). In this regard, forestry techniques across Europe range from total lack of managing caused by abandonment or protectionist policies to be restricted management or intensive short rotation forestry designed to provide electricity biomass (Pergola et al., 2022). However, management regimes that mimic natural disturbances can have a significant impact on stand structure, potentially leading to an increase in biodiversity over time while also reducing the rate at which forests undergo change (Kuuluvainen et al., 2021; Raihan, 2023b). Although forestry may have an effect on plant diversity and wildlife, it is generally less severe than agriculture practices due to the very inadequate usage of fertilizers, which are typically lone used for weeding prior to reforestation campaigns or to indulgence conifer over broad-leafed regeneration (Muys et al., 2022). Since the use of biocides is extremely rare in the forestry industry, managed forests employ these products at a fraction of the rate and with far less frequency than agricultural systems (Freer-Smith et al., 2019; Raihan, 2023c). The absence of tree species diversity, variation of tree phase, and unusual ecosystems like deadwood all contribute to managed forests having substantially lower biodiversity than natural forests (Freer-Smith et al., 2019; Raihan, 2023d). Given that stand age is a critical factor in the delivery of forest ecosystem services (Sutherland et al., 2016), it may be unfair to label it as yet another “victim” of modern forestry practices like clearcutting of medium-aged besides old stands, which may reduce the quantity and quality of forest functions (Jonsson et al., 2020; Raihan, 2023e).

Old growth forests are threatened by intensive forestry practices, which can lead to their temporary extinction (DellaSala et al., 2022). Unfortunately, the loss of biomass from old-growth and primary forests in Europe is continuing (Svensson et al., 2019), primarily for economic reasons, leading to a typical outline of forest degradation, comprising of the transformation of these surroundings into secondary forests (Angelstam & Manton, 2021) and the extinction of individual species dependent on deadwood or old trees (Raihan, 2023f). Finally, forest utilization practices (such as extracting non-timber goods, timber harvesting, converting natural forests to plantations, and roads and amenities construction) and the slow introduction of plant species for merchantable agroforestry practices can all contribute to the foreign invasive species introduction and proliferation (Ohimain, 2022). Figure 2 presents the environmental services and economic opportunities provided by the forests.

Economic utilization of forest resources and wood furniture supply chain

Even if the total forest area in Europe has remained relatively unchanged over time, this does not rule out the possibility of significant changes in the region’s forests. Both human activities, especially the removal of biomass; and ecological maturity or other natural processes affect forest ecosystems (Jaafar et al., 2020). Statistics from across the country supply data reflecting the depiction of the light and shade in the commercial utilization of forests, which may be deemed intensive only in particular regional scenarios, despite a general tendency toward broadening and asset under-use at the local level (Canadas & Novais, 2014; Raihan, 2023g). In fact, the average rate of forest usage (comparison of yearly volume lost versus yearly volume expansion of the remaining forest stock) across Europe in recent years has stayed far below 1 (EIR, 2018).

This suggests that there are prospects for larger harvests in various contexts and that, while timber production has differed by nation, it has persisted extremely sustainably. This presumption is based on a global scale analysis that compares national levels of GDP growth and consumer spending using varying data quality benchmarks. Some protected areas may not be viable if intensive logging is practiced on a regional scale (Bösch, 2021).

Figure 2. Environmental services and economic opportunities provided by the forests (FAO, 2023).

In some fractions of Europe (specifically in confined contexts in Eastern Europe), overexploitation of forest resources may still be an issue today (Bălăcescu, 2020). Even at a finer spatial scale (prefectures, municipalities), the situation is likely to get more convoluted. However, even in the most economically developed countries, accessible data rarely allows for such precision. In 2020, the total volume of timber in EU-27 woods was roughly 27.6 billion cubic meters (bcm). Germany and Sweden have the largest timber stocks amongst EU countries, totaling about 3.7 bcm (13.3 percent of the total EU-27).

Other countries with sizable wood reserves include France (3.1 bcm and 11.1 percent), Poland (2.7 bcm and 9.9 percent), Finland (2.5 bcm and 8.5 percent), and Romania

(2.4 bcm and 8.5 percent) (Forest Europe, 2020). In spite of the challenges it faces, these numbers show that Europe's forestry industry has room to grow economically and portray a positive function in the future of many countryside regions (Perunová & Zimmermannová, 2022). The conventional forestry segment (forest management, harvesting, sawmilling, forest products and processing) in the EU employs over 2 million people and generates a gross added value of more than €100 million per year (Tiebel et al., 2022). There are nearly 16 million private forest proprietors in the EU. Forests can be held by anybody from individual families to governments to investors in huge estates (Weiss et al., 2019; Raihan, 2023h). Yet over 60% of the forest area is owned privately (Maesano et al., 2018). By combining agricultural and forestry output, many farms provide economic diversification (Ficko et al., 2019). In 2017, the EU-27's forestry sector contributed 0.2% of the EU's entire GDP with a gross value added of 26.2 billion euros, a rise of 1.5% from the previous year. Finland, Sweden, France, and Germany accounted for just over 50% of the total value added. They were all worth between €3.2 billion and €3.8 billion. About half of the EU-27 countries had forestry account for gross value added below 0.3% of total. In contrast to the European average of 1.0%, this proportion was higher in Finland (1.9%), Latvia (1.7%), and Estonia (1.2%) (Forest Europe, 2020).

Nearly half a million Europeans have found work in the forestry sector in recent years, laying the groundwork for a wide range of rural sectors and professions, such as forest management, tourism, wood industries, and hunting (FAO, 2020). But the manpower requirements of logging and forestry vary widely among the Member States. Kajanus et al. (2019) note that the pattern and peculiarities of individual forest, tree density, species affected from the harvesting activities, and the topography landscape all have a role in the possibility for effective utilization of forest modernization. Poland (73,000), Romania (48,000), Sweden (41,000), and Germany (40,000) had the highest employment rates (Da Silva & Schweinle, 2022). There was a little drop (-0.2%) in forestry jobs in the EU between 2008 and 2018 (Cook, 2020). Eastern European countries like Hungary (+50%, with over 7,000 more employees) and Poland (+11%, with more than 11,000 new jobs, equal to +18% over the last decade) have seen increases in their employment rates in recent years. To the contrary, Croatia saw the largest decline in forestry employment (-55%, or 17,000 jobs) over a ten-year period (FAO, 2020).

The principal goods of forestry, along with fuelwood, industrial roundwood is an essential material for the manufacturing of sawn wood and veneers. According to Brack (2018), Europe is a major player in the global roundwood market. The EU-27 countries rely heavily on the manufacturing of timber products (Lovri'c et al., 2020). In 2018, the wood industry's 397,000 businesses accounted for nearly a fifth of the overall manufacturing segment. These businesses directly or indirectly employed 3.1 million people (10.5% of the manufacturing sector's workforce) and generated 138.6 billion euro in added value. According to data from 2018, 19.6% of all manufacturing establishments in the European Union were involved in the manufacture of wood commodities (Cook, 2020). When compared to the percentage of value added (7.1%), it is obvious that small and medium-sized firms (those employing between 51 and 249 people) are the backbone of the wood production industry (Socoliuc et al., 2020).

Europe's roundwood output has been on the rise over the past few decades, with a temporary dip in 2007–2008 due to the economic catastrophe. However, manufacture has shown encouraging signs of recovery since 2010, and has fully regained to pre–crisis stages (458 million m^3) since 2013 (Schier et al., 2022). Recently, it was anticipated that output was 490 million m^3 in 2018, an increase of 5.5 percent from 2017 and a considerable increase of 21.2 percent from 2000 (FAO, 2020). Hardwoods showed remarkable stability in output while conifers, which account for three-fifths of the entire roundwood output (60.4%, or 296 million m^3), showed greater volatility (Cook, 2020). The number of cubic meters of roundwood harvested in Sweden in 2018 was 75.1% higher than in 2017, at 75.1 million. German roundwood production (71.8 million m^3), Finnish roundwood production (68.3 million m^3), French roundwood production (48.2 million m^3), and Polish roundwood production (46.9 million m^3) together account for nearly two thirds (63.3 %) of the EU's roundwood production. In 2018, it was predicted that the European Union's total sawn wood production was 109 million m^3, up from a decade earlier (+11.7%). Sawn timber production in the EU remained led by Germany (21.9%) and Sweden (16.9%), as in previous years. Only Finland in the European Union (EU) recorded a double-digit percentage of global wood production (10.9%). Germany (+4.6 million m^3, or +23.7 percent), Finland (+2.0 million m^3, or +19.8 percent), and Romania (+1.3 million m^3, or +35.9 percent) were the primary contributors

to the EU's rising sawn wood production between 2008 and 2018.
However, total EU roundwood production fell by 2% from 2019 to 2020, to 488 million m^3, ending an eight-year period of continuous growth (Eurostat, 2021). In spite of this, roundwood output is 21% higher than it was in 2000. Figure 3 presents the percentage change in roundwood production in the EU between 2000 and 2020. Since 2000, roundwood production has increased across the board, with the largest increases being in the Netherlands (+185 percent), Slovenia (+73 percent), Germany (+57 percent), Poland (+56 percent), Croatia (+43 percent), and Romania (+37 percent). Some of those nations had quite humble beginnings. Cyprus (-58 percent), France (-28 percent), and Hungary (16 percent) saw the biggest percentage drops in their respective annual wood harvests (Eurostat, 2021).

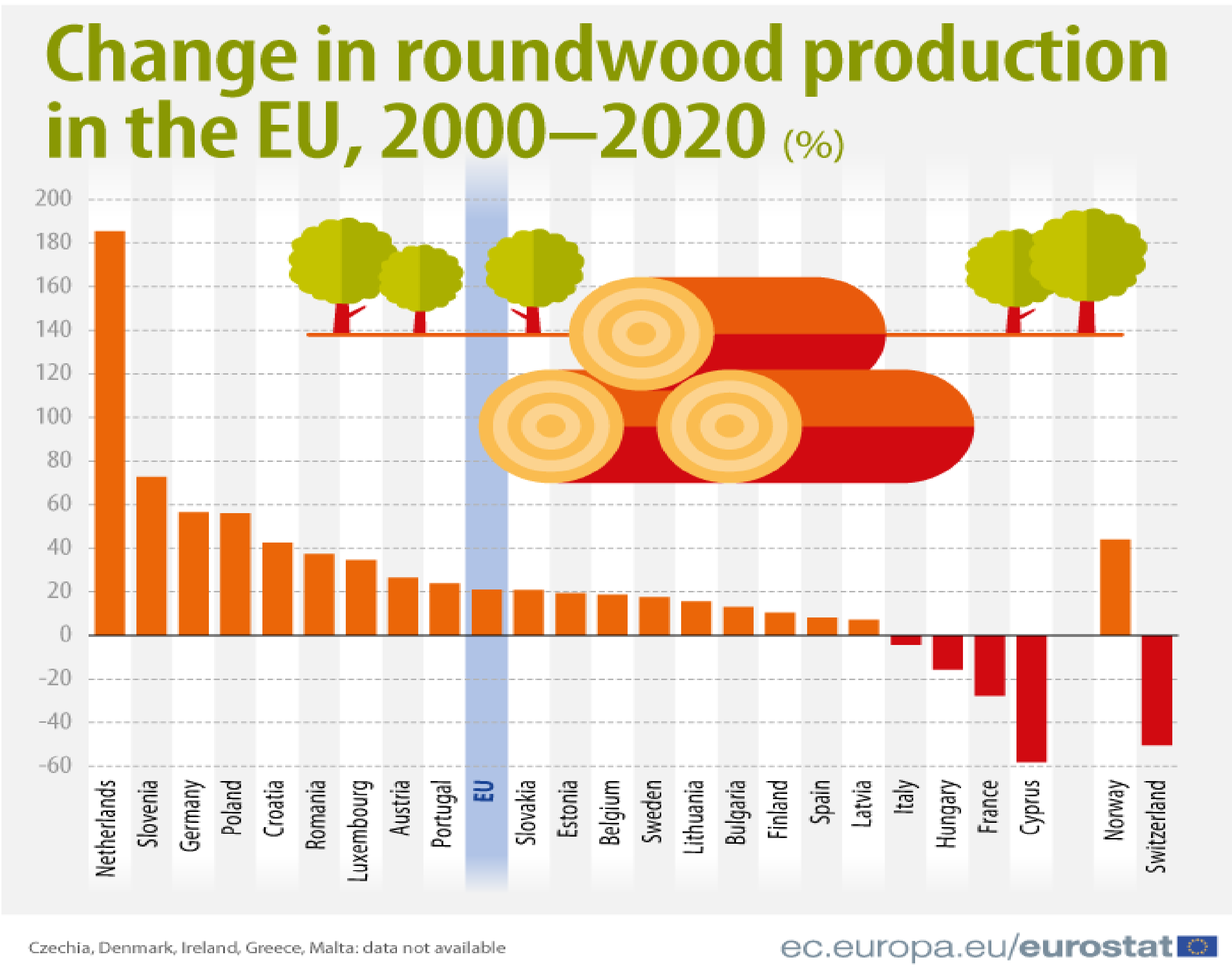

Figure 3. Percentage change in roundwood production in the EU between 2000 and 2020 (Eurostat, 2021)

The usage of wood as a sustainable energy source has been on the rise. In 2020, about a quarter (23 percent) of EU roundwood production was used for fuelwood, while the remaining 77% was used for industrial purposes such as sawing, veneering, or pulping and papermaking. The percentage of total wood used for fuel therefore increased by six percentage points since the year 2000. Fuelwood constituted the bulk of roundwood output in some Member States in 2020; the Netherlands (78 percent) and Cyprus (74 percent). In contrast, over 90 percent of roundwood production in Slovakia and Sweden was reported to be industrial roundwood (Eurostat, 2021). Notwithstanding the above economic data's testimony to the health of the wood-furniture supply chain, the European wood business has felt the effects of the decline in manufacturing employment, especially between 2000 and 2019 (9.6%)

(Marschinski & Turegano, 2019). The integer of people engaged in the production of furniture and wood merchandise fell by nearly a quarter (26.3% and 24.9%, respectively) and men progressively made up the majority of these industries' workforces (Cook, 2020). More than 80% of workers in the forestry industry were men in 2019, but only 83.4% of those employed in the production of wood and its end product were men (Cook, 2020). Similarly, only 77.3% of those employed in the furniture manufacturing industry were men.

European policy context and new developments in forestry

As deforestation is expected to cause a widespread loss of forest canopy and wooden assets in numerous regions, the European Commission is working to increase protections for forests by promoting global value channels not leading to deforestation or forest degradation. Since 1980, the European Union (EU) has established forestry sector guidelines and action programs that are sometimes applied in the Common Agricultural Policy (CAP), especially in rural development policies (Sarvaová et al., 2019). During the 1990s, forestry went from being a tertiary component of the CAP to an integral part of European sustainable development policy, leading to the adoption of the EU's Forest Policy in 1998 (Galiana et al., 2013; Raihan, 2023i). It served as the very first benchmark guideline to include Member State action instructions in line with sustainable forest management principles (Rametsteiner & Mayer, 2004; Raihan, 2023j). The 2005 Forest Action Plan (FAP) served as the primary mechanism for putting the Strategy into action, with the stated goal of "enhancing the forest heritage of the Union, maintaining and strengthening the multifunctional role of forests through active and aware management of the forests" (Aggestam & Pülzl, 2020). To increase the availability of renewable and ecologically friendly raw materials, the function of forests was bolstered in climate change mitigation and adaptation guidelines with the introduction of the new European Forest Policy in 2013 and subsequent amendments (Aggestam & Giurca, 2021). Figure 4 presents the policy areas pertinent to forest policy in the European Union.

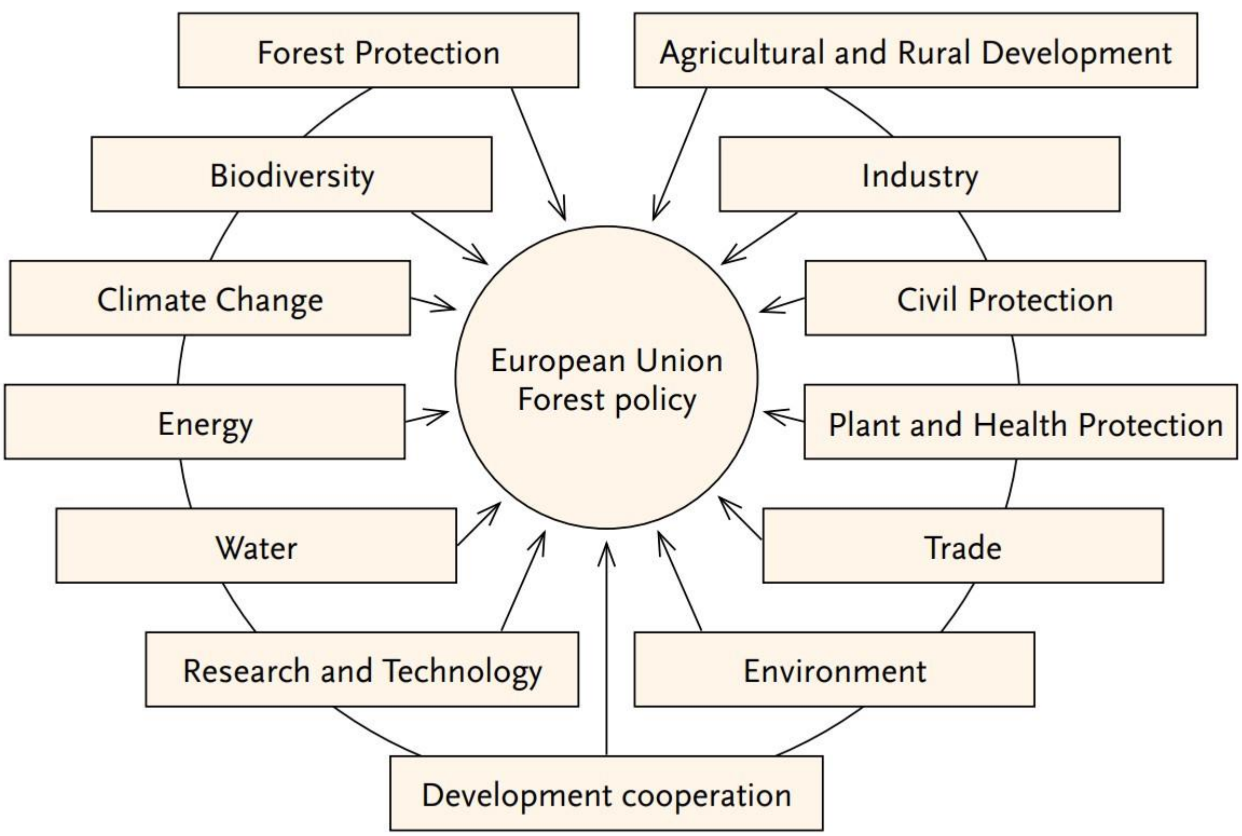

Figure 4. Policy areas pertinent to forest policy in the European Union.

The forest policy has provided a uniform structure for community strategies and a fine-tuning of the forest strategies of each member country (Falcone et al., 2020; Aszalós et al. 2022). This is all in service to fostering sustainable forest management with an eye toward effective resource utilization. Rehabilitation, resiliency, and proper preservation of all ecosystems, not only those characterized by forests, must be a primary priority to achieve a sustainable and climate-neutral economy by 2050 (Fetting, 2020; Raihan et al., 2022i). This new community strategy is strongly rooted in the Green Deal and the biodiversity policy for the 2030 Agenda objective. These measures sought to improve the conservation and restoration of forest resources, increase sustainable management, and boost monitoring and the effectiveness of distributed organizing so that these ecosystems could perform a multifunctional part in mitigating GHG emissions and sequestering CO_2 equivalents (Palah et al., 2020). This approach also includes efforts to promote the development of alternative resources and goods in addition to those of fossil sources and to encourage the growth of a forest economy that is not dependent on the harvesting of trees (Ladu et al., 2020; Viaggi et al., 2021). This is to further support a sustainable forest bio-economy for a future with zero climate impact. This included ecotourism based on the new strategy switching to the EU Forest Policy approved in 2013 and reviewed in 2018. The updated plan was released in July of 2021. Finally, a plan for planting as a minimum 3 billion more trees in the EU by 2030 was included next to the strategy's emphasis on sustainable reforestation (and afforestation) (Lee et al., 2023).

This tactic is tied to the CAP by design and benefits from the CAP's operational interventions, which help make rural areas more thriving and prosperous (Lier et al., 2022). The major financial support for the safeguarding and sustainable management of communal forests comes from these initiatives, which encourage versatile forestry and sustainable forest management and combine it with additional growth indicators (advice and offerings, education, expenditures, collaboration) that react to particular regional requirements (Gordeeva et al., 2022). These measures also encourage forest growth through reforestation and the revival of agroforestry arrangements; they furnish operative and monetary instruments for fire and disaster preclusion; restoration following damage; investments in climate change adaptation and mitigation; and economic procedures for compensation and inducements for boosting the monetary worth of woodlands and pre-industrial timber (Ascoli et al., 2023). In a highly dynamic environment such as the present one, the European Commission has articulated the Next Generation EU as a solution to the catastrophe due to the epidemic, with the three struts being social interconnection, the green economy, and the digital transformation (Fabbrini, 2022). From this vantage point, the Carbon Border Adjustment Mechanism seeks to shield EU-made goods from less environmentally friendly imports made by countries beyond the EU's borders (Mörsdorf, 2022). The "Fit for 55" package mandates that the region become carbon neutral by 2050, with the interim objective being reached by 2030 (Köhl et al., 2021; Raihan, 2023k).

Because they are seen as vital (and steadily increasing) contributions in the shift and advancements of renewables, member nations will also be expected to meet a goal for the allocation of key basic equipment. The European Union estimates that the furniture industry could benefit from the circular economy by creating an additional 160,000 jobs, reusing or recycling an additional 3.3 to 5.7 tons of materials, preventing the emission of an additional 3.3 to 5.7 metric tons of carbon dioxide equivalent, and increasing the value of the local economy by 4.9 billion euros. Because of this, Baumgartner (2019) argues that supply of wood and the furniture business have the problem of moving quickly enough to fully capitalize on the prospects presented by a truly sustainable development. However, the EPA (Environmental Protection Agency) confirmed in 2018 that biomass burning can be classified as an emission-free energy resource (Raihan & Tuspekova, 2022i; Raihan et al., 2023g). This fundamental assertion endures to handle worldwide efforts on climate change despite the lack of scientific evidence. However, most academics agree that switching back to firewood as an energy source will significantly exacerbate the environment and pose a hazard to forests (Schlesinger, 2018; Raihan & Tuspekova, 2022j). To compound matters for businesses producing high-quality wood goods like furniture manufacturers, this political stance will have a detrimental effect on the availability of wood supplies.

Discussion

This research provides actual evidence for the intricate ecological-economic nexus that drives forestry and the forest industry as a whole. Ecologically speaking, a deeper understanding of forest ecosystems is a vital piece of data needed to support a competitive supply chain strategy aimed at achieving the Sustainable Development Goals (Moreau et al., 2022). These goals were implemented by all nations as a feature of the United Nations 2030 Agenda and aim to protect the environment and reduce greenhouse gas emissions. Miina et al. (2020) and Rosa et al. (2023) note that current data on forest management techniques in Europe is insufficient to provide an inclusive picture of ecological health, economic assessment, and biodiversity. In addition, it is possible that national statistics are incomplete since they exclude logging operations that serve essential (and likely informal) needs, such as house heating (Picard et al., 2021). There is an immediate need for more precise statistics on forest management techniques and their influence on forest reserves, as well as more accurate measurement of forest land-use and associated change over (Gschwantner et al., 2019; Raihan, 2023l). Better data on forest area and management changes will be available thanks to remote techniques (Chirici et al., 2020; Filizzola et al., 2022). High-resolution data on forests, including the density of tree cover, type of forest, and characteristics of small woody trees, will be made available through the European Environment Agency's (EEA) adoption of the Global Monitoring and Environmental Surveillance (GMES) system (Chianucci et al., 2021). An exact monetary assessment of resource reserves, that is yet lacking at present (Loomis et al., 2019; Raihan, 2023m), requires all of this data.

Sawmills and other forest-use infrastructure are progressively disappearing across Europe, despite the region's relatively constant wood and other commodity production. The opposite is true; forest cover and volume, along with forests' ability to sequester carbon, have grown steadily over the past few decades. While this is encouraging, it also comes with a caveat: the forests are increasingly at risk from both natural disasters (such as change of climatic conditions, floods, and landslides) and agrarian desertion, that can cause economic uncertainty and ecological deprivation, particularly in poor and remote areas (Angra & Sapountzaki, 2022; Zhang et al., 2022). Official statistics face a challenge when they are tasked with assessing the forest reserve, primarily in relations to good-quality wood intended for the furniture manufacturing chain. These statistics are meant to support a broad outline of economic and environmental trends to the aggregate user, with the goal of encouraging enhancements in records inclusiveness, statistic consistency, and timely update. By working together more closely, member nations and regional authorities can improve the quality of economic analyses and plan for the more efficient and environmentally friendly utilization of forest resources (Edwards et al., 2022). Due to the multifaceted nature of forest supply chain issues, it is challenging to keep tabs on them using only official statistics (Garcia & Hora, 2017; Raihan, 2023n). While confirming the necessity for a larger interpretation of the many organizational components, such as the problem of assessing natural resources, in the economic analysis, this paper does the opposite. For instance, incomplete statistics, inconsistent methodological definitions, and sparse geographical detail continue to define this axis in the present day.

To keep products, components, and materials as valuable as possible within the economy for as long as possible, area operatives appear to gain a heightened knowledge of the magnitude of investing at the firm level (Mhatre et al., 2021). These measures, which call for a shift in corporate, territorial, and individual perspective and a fundamental rethinking of the way we produce and consume, are intended to steer the manufacture and consumption structures toward further effectual pathways by means of incessant and reformative sequences that reduce resource use, waste, and emissions in manufacture procedures (Sahoo et al., 2019; Raihan et al., 2022j). The adoption of circular techniques that ensure environmental sustainability over the medium term is increasingly common across all industries, with circular principles progressing most rapidly across furniture manufacturing firms, the supply chain's most dynamic link (Jarre et al., 2020; Raihan & Voumik, 2022b).

Most of the resources utilized in the manufacture of lumber appear to be destined for incineration or disposal. Dead branch off, barks, residues, and debris are typically simply seen as something to be thrown away. Despite being classified as waste, these materials may have a happy ending after all, leading to a valuable second use and a strong market position (Pieratti et al., 2019; Raihan, 2023o). Most mulch on the market has traveled from far away to get to your garden. This adds a new dimension to the quest to reclaim the abandoned bark. Barks and dead branches are often burned for cheap thermoelectricity, despite the fact that they can have significant nutrient value and serve an important role in soil protection. In addition to peat and other soil conditioners, residues can be used as a high-carbon fertilizer. The usage of "cascade" timber is encouraged in a circular forest management system. It entails giving material recovery a higher priority than wood combustion for energy production. The implementation of this idea benefits the regional timber supply chain and the economies of communities located in economically vulnerable locations near woods (Jarre et al., 2020; Raihan, 2023p). In this view, a tree trunk is a resource that should be put to good use across multiple industries, from construction and interior design to paper production and textiles.

As Mair and Stern (2017) point out, "cascade" wood is a great way to practice thinking about forests as resources with multiple uses that benefit both the environment and human society. As such, effective info campaigns and territorial passageway constructions, unspoken as vital ideologies of data and distribution of information and performs, are necessary for interventions on the timber-furniture supply chain labor market, especially in light of the sustainability of environmental and the transition of energy more generally (Marcinek & Smol, 2020; Raihan, 2023q). Companies in the supply chain have been shown to have a heightened recognition of the significance of energy and climate challenges, as well as the insistence of strategic solutions to environmental concerns (Adami & Schiavon, 2021; Lazaridou et al., 2021; Raihan & Tuspekova, 2022k). The potential for economically encouraging and promoting active enterprises from a viewpoint of not only positive environmental behavior, but also of technological advancement, ensures a fair transition on all fronts (economics, ecology, and information) toward novel manufacturing circumstances which are sustainable across a long period and resiliency to swift worldwide shifts in societies and environmental systems (Marques et al., 2020).

Conclusion

This paper looked at the many ways in which forestry contributes to society economically, including the formation of additional occupations, the revitalization of rural areas, and the improvement of people's physical and mental health through leisure activities. In addition to the direct economic benefits, forestry also benefits from the downstream input of wood, which is used extensively in the timber sector and continues to perform a large responsibility in the global energy mix. An increasing number of people are beginning to recognize the social and ecological advantages of ecotourism and additional practices of sustainable forest management. In this setting of opposites, the regulatory and institutional structure is highly variable and inconsistent in its ability to safeguard the sustainable management and protection of forests. It is strongly suggested that in the following years, new technical and product developments, as well as new legislative and programmatic tools, be implemented.

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