



Decoupling REDD+ understanding of local stakeholders on the onset of materializing carbon credits from forests in Nepal



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ABSTRACT

REDD+¹ is an economic incentivizing mechanism aimed at reducing or offsetting of carbon emissions in forests, while realizing multiple benefits alongside climate action. Engaging local stakeholders is crucial for its sustainable implementation and benefit-sharing mechanism. This study focuses on the knowledge and understanding of local-level stakeholders about REDD+ and its associated attributes, revealing significant knowledge gaps between areas with and without REDD+ pilot activities. For this, we conducted the semi-structured questionnaire interviews ($n = 136$), key informant interviews ($n = 27$), and focus group discussions ($n = 4$) with local-level REDD+ stakeholders (LLRS) comprising both inside and outside of pilot project districts in three provinces of Nepal, by adopting the concept of socio-ecological systems (SES). Data were analyzed using a generalized linear model (GLM) and visualized through Sankey diagrams. The results indicate a poor understanding (29%) of LLRS on the REDD+ process, its relationship with forests, concerns among stakeholders, and its potential significance. The perception of REDD+ knowledge, mechanisms, and benefits significantly ($p < 0.05$) varied across study areas, age groups, genders, professional backgrounds, educational levels, ownership of private forests, and types of household energy sources used among respondents. Despite receiving readiness funds, stakeholders' comprehension of the REDD+ process remains limited, indicating suboptimal policy implementation. Knowledge gaps were influenced by social background, voices and choices, and the fear of REDD+ disrupting traditional practices among the LLRS. The study emphasizes the need to redress the concerns of LLRS by considering their social backgrounds and traditional practices through informed and participatory decision-making, enhance communication, transparency, and inclusive forest governance. The findings show that current external support has not sufficiently enhanced capacity among LLRS, suggesting the need for sufficient and sustainable support through national policy and financing mechanisms. Further, the study identified extremely poor REDD+ -related knowledge dissemination within communities, exacerbating challenges in implementation and benefit-sharing mechanisms, revealing the simplification of its process is essential. The study advocates for revising REDD+ -related policies to optimize benefits, ensure smooth implementation, realize fair and equitable carbon credits from forests, and foster shared responsibility and ownership among all stakeholders in climate actions through improved forest governance.

1. Introduction

The dual role of forests—both in adaptation and mitigation—was recognized in global climate policies following the Rio Earth Summit, as

outlined by the United Nations Framework Convention on Climate Change (UNFCCC) framework (Watson et al., 1992; UNFCCC, 2023)¹. Along with the ability to adapt and regulate climate, water, and soil, support biodiversity, and provide essential services to humankind,

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¹ Reducing emissions from deforestation and forest degradation (REDD), plus conservation and enhancement of carbon in the forests, and sustainable forest management in developing countries is collectively termed REDD+

forests also play a crucial role in mitigating climate change. They act as sources of greenhouse gases (GHGs) during deforestation and degradation, while serving as sinks of GHGs during regeneration, stock conservation, and sustainable management (Watson et al., 1992; Dixon et al., 1993; Kirschbaum, 2003). This role in mitigating GHG emissions of forests is well-documented (Fry, 2008; Pistorius, 2012). An environmental mechanism known as 'REDD+' has been implemented in developing countries to achieve this goal from the forests (Corbera and Schroeder, 2011; Wunder et al., 2020; Skutsch and Turnhout, 2020; Maraseni et al., 2020), aiming to offset GHGs while adhering to UNFCCC principles (UNFCCC, 2023). Through this mechanism, countries can voluntarily participate in readiness processes, respecting and engaging the traditional rights of Indigenous people, local communities, and other stakeholders regarding their forests (Weeks and Filardi, 2011; Patel et al., 2013; Aguilar-Støen, 2017; Poudyal et al., 2020). These readiness initiatives seek to operationalize multiple forest uses and optimize their co-benefits for various stakeholders (Aziz et al., 2016; Boutthavong et al., 2017; Maraseni et al., 2019). Initially, as an emerging climate governance mechanism, REDD+ -related pilot projects have been implemented in developing countries, involving multiple stakeholders at the grassroots level (Yeang, 2010; Pandit et al., 2017; Massarella et al., 2018; Maraseni et al., 2020). However, the significant impacts of these REDD+ readiness projects at the grassroots level have been inadequately examined. It remains unclear whether these projects enhance the knowledge and understanding of REDD+ among local stakeholders to facilitate further implementation steps and devise effective benefit-sharing mechanisms.

The mapping of stakeholders' engagement and their understanding of REDD+ serves as a cornerstone for contextualizing benefit-sharing mechanisms and analyzing common ground among local stakeholders (Weeks and Filardi, 2011; Garnett et al., 2018). This approach paves the way for more effective, efficient, and equitable distribution of benefits and responsible stewardship by local communities (Kirschbaum, 2003; Yeang, 2010; Dawson et al., 2018; Wong et al., 2019). Additionally, incorporating locally perceived values into decision-making processes can contribute to the sustainability of forest ecosystems (Piya et al., 2011; Kandel et al., 2018; Aryal et al., 2023; Pandey et al., 2023) and optimize economic and other co-benefits for people's livelihoods (Khadka et al., 2014; Dawson et al., 2018). Recognizing these facts, several studies have been conducted to understand the various dimensions of REDD+ on the ground worldwide. Some of these studies have investigated the evaluation of local perceptions in various countries. For instance, research has explored the perception of REDD+ knowledge in African countries (Tiani et al., 2015), examined benefit-sharing mechanisms within the context of local legal rights in Ethiopia (Pham et al., 2021a), investigated local perceptions in Tanzania (Uisso et al., 2022), and analyzed the participation of women in the REDD+ process in the Democratic Republic of Congo (Stiem and Krause, 2016). Similarly, other research has explored the involvement of stakeholders in REDD+ readiness activities in Lao PDR (Boutthavong et al., 2017) and mapped various initiatives across the Asia-Pacific region (Maraseni et al., 2020). However, these studies were piecemeal and focused solely on REDD+ pilot areas. To the best of our knowledge, no studies have compared stakeholders' understanding of REDD+ between pilot project areas and regions outside of them.

In Nepal, one of the pioneering REDD+ countries, comprehensive multi-stakeholder engagement processes have been embraced since 2010 (REDD Cell, 2014). The country has executed several pilot projects, reporting effective outcomes in enhancing the capabilities of local-level REDD+ stakeholders (LLRS). These efforts focus on reducing carbon emissions, supporting biodiversity conservation, and enhancing livelihoods through a participatory approach (Paudel, 2013; Maraseni et al., 2014; Rana et al., 2017). Nepal's commitment to these activities has yielded promising results, covering various aspects from policy to practical implementation related to REDD+ readiness (MoFSC/REDD, 2015; REDDIC, 2016). These results include ensuring essential social safeguards (Lemaitre, 2011; De La Fuente and Hajjar, 2013; Aguilar-Støen, 2017) and guaranteeing environmental integrity (Poudel et al., 2015;

Rana et al., 2017; Maraseni et al., 2020), aligning with national and international policy visions (Government of Nepal, 2018, 2019). Further, significant progress has been made in REDD+ implementation in Nepal, including the approval of emission reduction program documents (REDD/MOFE, 2018) and the signing of an emission reduction purchase agreement (ERPA) with the World Bank Team under the Forest Carbon Partnership Facility (FCPF) on February 24, 2021. In line with this progress, scholarly works have also surged, focusing on various aspects of REDD+. For example, understanding the REDD+ process based on responses from collaborative forest management users (Gilani et al., 2017), analyzing the economic costs and benefits of carbon (Pandey et al., 2014a; Pandit, 2018), and examining governance and challenges (Khatri et al., 2012; Paudel, 2013). Studies have also addressed social equity, livelihood, and forest management within REDD+ pilot projects (Patel et al., 2013; Maraseni et al., 2014; Pandey et al., 2017), environmental outcomes (Poudel et al., 2015; Maraseni et al., 2020), and the role of media in REDD+ politics (Khatri et al., 2012; Pandit, 2018). However, these studies largely overlook the knowledge of LLRS beyond pilot project areas, who are directly involved in REDD+ implementation and benefit-sharing mechanisms at the grassroots level (MoFSC/REDD, 2015; Garnett et al., 2018; Mulder et al., 2021). Due to the limited involvement of the environmental organizations in capacity building, producing policy documents, and developing carbon monitoring methodologies at international and local levels (Aryal et al., 2024), there has been a prolonged period of inaction regarding REDD+. It is now time to devise a fair and equitable benefit-sharing mechanism without hurdles, in a participatory manner, as the understanding and knowledge mapping of ground-level stakeholders is crucial yet insufficiently documented (Bastakoti and Davidsen, 2015; Paudyal et al., 2015; Pandit, 2018; Aryal et al., 2024). Such an assessment is necessary to substantiate knowledge and understanding, facilitating informed decision-making for future pathways (Chhatre et al., 2012; Bernard et al., 2014; GoN/MoFE, 2021; Pandey and Pokhrel, 2021).

In this context, our study seeks to address two main research questions. Firstly, it aims to compare the knowledge of REDD+ among local stakeholders who have received external support (pilot project area) and those who have not. Secondly, it assesses whether the understanding of REDD+ is strong enough to implement benefit-sharing mechanisms tied to performance-based payments at the grassroots level, related to the social assets of local-level REDD+ stakeholders (LLRS). To address these questions, we evaluated the knowledge and understanding of local-level stakeholders regarding REDD+ and its associated attributes, using a case study of Nepal's Terai region, applying generalized linear models (GLM). Additionally, we visualized subjective categorical relationships through Sankey diagrams (Bakken et al., 2016), with a specific focus on local contexts within the lowlands' social-ecological landscape, and we discussed the key findings for future policy and practical implications to enhance the ground-level knowledge in these disciplines. The findings will serve as a reference to better implement the benefit-sharing mechanism and advance REDD+ implementation in Nepal and beyond.

1.1. Theoretical and conceptual framework

The overall research has been guided by the concept of social-ecological systems (SES) (Ostrom, 2009), which assumes that interactions between individuals and their environment are reciprocal. This means that an individual influences their environment while being simultaneously influenced by it. This concept addresses the actions and interactions of resource systems, resource units, governing systems, and the interplay of actors across the socio-ecological system in a dynamic environment. As REDD+ is a new approach under the framework of the UNFCCC, it requires decisions at the international institutional level and then needs to be voluntarily adopted at the (sub)national level (Anderies et al., 2004; Ostrom and Cox, 2010), linked with the governance system of the SES. Further, REDD+ concerns the forest ecosystem (i.e., resource units of SES) connected with the users (in our case, LLRS, i.e., actors

under the SES concept) and interlinked with socio-economic, cultural, ecological, and environmental systems (i.e., resource systems) of those resources, including carbon services. This broadly falls under the umbrella of an SES (Ostrom, 2007, 2009; Ostrom and Cox, 2010).

Decisions on REDD+ encompass social, economic, and political governance related to forest ecosystems, benefiting both human and non-human spheres. With the SES concept in the background, we adopt a participatory approach to assess local knowledge of the REDD+ process. This approach focuses on areas where the intended beneficiaries, such as Indigenous and local communities reside and where decisions directly affect them. The localization of the REDD+ approach has garnered valuable insights from previous participatory integrated conservation and development projects (Blom et al., 2010) and is instrumental in addressing local concerns related to Indigenous and local communities during REDD+ implementation (Poudyal et al., 2020). Recognizing these considerations and aiming for a broad understanding of the REDD+ process in Nepal, key attributes were developed and validated among staff working in the REDD Implementation Centre (REDD IC), Kathmandu before being finalized for inclusion in the questionnaires.

Broadly, this study utilizes an input-process-output-outcome-impact conceptual framework to guide the overall research process, considering the socio-ecological attributes of the study areas (Fig. 1).

2. Methodology

2.1. Study area

For this study, we selected three Terai (lowland) districts, each from three provinces: Bagmati Province–Chitwan District, Koshi Province–Jhapa District, and Madhesh Province–Saptari District (Fig. 2). In order to maintain coherence in the socio-ecological environment of the study area, we selected all districts that border India to the south and

have similar socio-economic conditions and geographic locations. Chitwan District was chosen because it is one of the REDD+ pilot project areas where externally funded projects for REDD+ readiness and capacity building are currently considered for the ERPA (Emission Reduction Payment Agreement) performance-based payment mechanism. However, the other districts have not received any dedicated readiness external funding (REDD/MOFE, 2018), instead, they have been identified as potential areas for REDD+ (MoFSC/REDD, 2015).

The Chitwan District has hosted projects such as REDD+ Himalayas in the Kayarkhola watershed by the REDD IC, and has been considered under the Emission Reduction Purchase Agreement. Additionally, Chitwan is home to the forest-dependent Indigenous community known as the Chepang. As part of our data collection, we conducted a group discussion with this community, engaging them as key informants and respondents in semi-structured interviews to gather key insights from this marginalized Indigenous community on the topic.

The Saptari District, belonging to Madhesh Province, has not dedicated REDD+ projects yet. However, it occasionally receives funds for capacity building directly from REDD IC. The district is home to a substantial population of Indigenous communities, specifically the Musahar. Given their strong reliance on forests for livelihood, we conducted a group discussion with the Musahar community during our data collection. The Jhapa District, part of the Koshi Province, has also not received dedicated funding for REDD+ projects or public funds for readiness efforts. Nevertheless, sporadic capacity development activities have been facilitated by REDD IC, similar to those in Saptari District. Notably, Jhapa boasts the largest group of registered private forest owners in Nepal. Recognizing the significance of private forest owners as a key category within the local forest-related community, we conducted a focus group discussion with this group. Additionally, as part of our study in this district, we engaged with the Indigenous Tharu community.

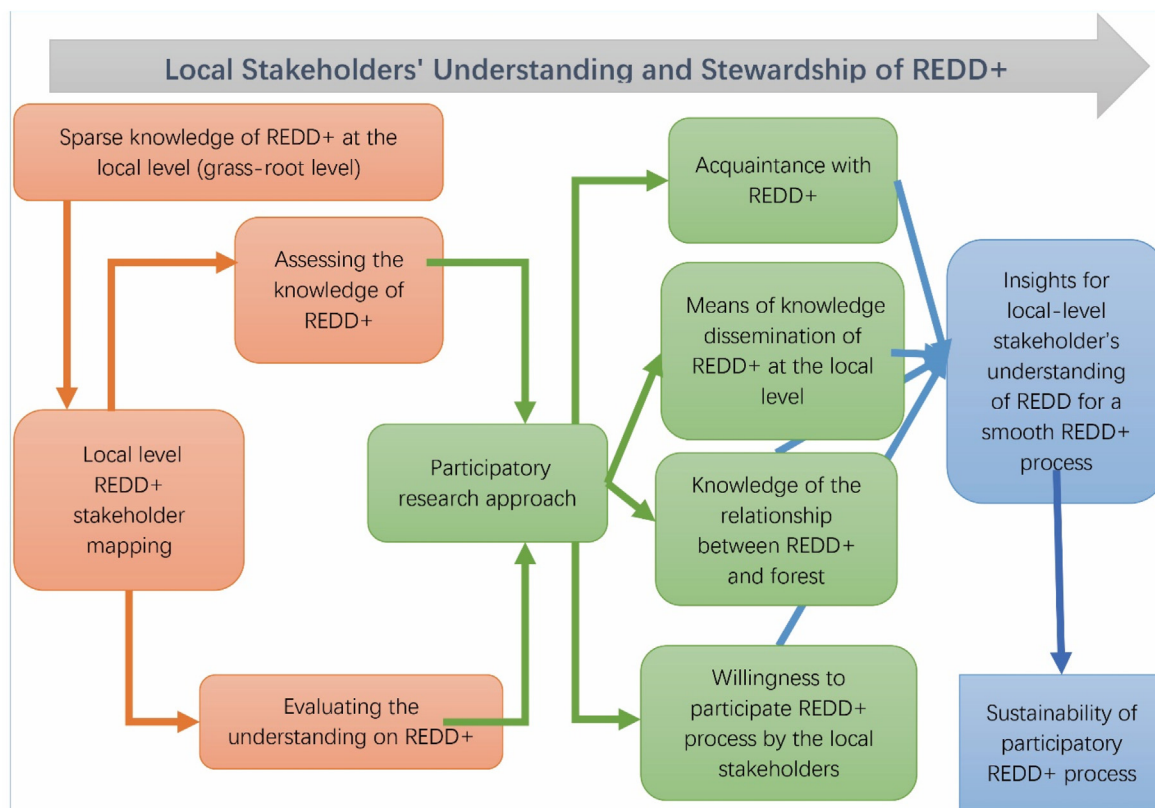


Fig. 1. The conceptual framework of the study and its implications. Different colors have no meaning other than making the themes distinct. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

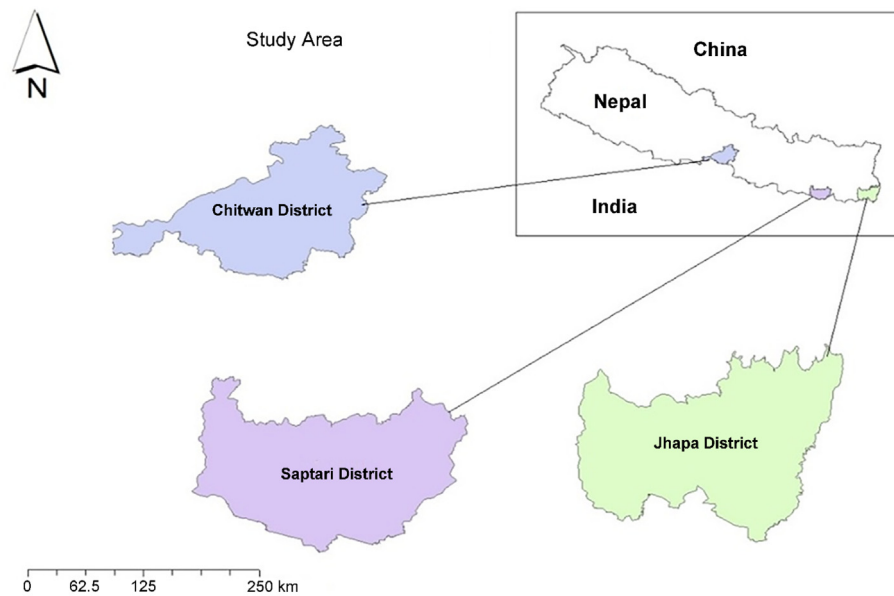


Fig. 2. Map showing the study areas. All the districts share the same social-ecological landscape of lowlands, border India (transboundary), and represent three different provinces of Nepal. Chitwan belongs to Bagmati Province, Saptari to Madhesh Province, and Jhapa to Koshi Province in the lowland landscape of Nepal.

2.2. Data collection

2.2.1. Semi-structured questionnaire interviews

A participatory research design approach was employed, integrating qualitative and quantitative methods to achieve a comprehensive perspective. Three key methods were used to avoid bias, i.e., questionnaire interviews, focus group discussions (FGDs) and key informant interviews (KIIs). While constructing the questionnaire, we selected and customized variables based on references from prior studies worldwide (e.g., Yeang, 2010; Alemagi et al., 2014; Tiani et al., 2015; Gilani et al., 2017; Uisso et al., 2022), and finalized the most relevant attributes after validation from experts in the field ($n = 5$). Collaborating with a panel of experts, referencing relevant previous studies, and adopting a resource-friendly participatory approach, we tailored and adapted the questionnaires to the local socio-economic conditions of the Nepalese participants at the grassroots level. Subsequently, key testable variables were identified for further analysis (Table 1). The semi-structured questionnaires were designed to be conducted in the native language, Nepali (Supplementary File_S1), and were divided into three main categories: basic understanding of REDD+, the relationship between forests and REDD+, and socio-political considerations of REDD+ in the local context, in line with the SES concept. The questionnaire mainly consisted of closed-ended questions that allowed respondents to choose from predefined options, along with a few open-ended questions aimed at gathering comprehensive information.

To ensure the study's resource availability and methodological simplicity, we conducted oral interviews with a sufficient number of local forest-dependent REDD+ stakeholders, as recommended by Bürgi et al. (2013) for participatory research and adopted the methodological approach referenced by Pandey et al. (2023). Initially, two-day workshops were organized in each selected district to gather preliminary information and raise awareness about the study's objectives. Workshop participants were identified based on the Government of Nepal's REDD guideline for forest-related stakeholder mapping (MoFSC/REDD, 2015). Specific criteria were established for participant selection: 1) Affiliation with the local-level REDD desk, coordinated by the Divisional Forest Office (formerly known as the District Forest Office), comprising forest and REDD-related stakeholders; 2) Residency in the same district, with exceptions made for civil servants working within the district, and a minimum of three decades of involvement in forest-related activities or

direct concerns related to forests; 3) Provision of insights into climate change, REDD+, and sustainable forest ecosystem management based on

Table 1

The characteristics detailing and the coding strategy for the analysis.

Code	Dependent variables (binomial distribution unless otherwise stated)	Code	Independent variables (binomial distribution unless otherwise stated)
Q1	Heard about REDD+ (yes = 1, no = 0)	District	Districts (Chitwan, Jhapa, Saptari)
Q2	Where do you know about REDD+? (media = 1, no = other, e.g., Education, neighbor, tea talk, etc.)	Age category	Age in years (if age $\geq 50 = 1$, less than 50 = 0)
Q3	Relation between forest and REDD+ (yes = 1, no = 0)	Sex	Gender (female = 1, male = 0)
Q4	What relation know? (carbon trade, mitigation, income source = 1, otherwise = 0 (including do not know responses))	Profession	Major profession (agriculture = 1, otherwise = 0)
Q5	Which aspect does REDD+ address? (mitigation or adaptation or resilience = 1, do not know = 0)	Education	Educational level ((university - tertiary) = 1, schooling and literate = 0)
Q6	Do you know carbon trading from forests? (yes = 1, do not know = 0)	Q15	Owning private forest (yes = 1, no = 0)
Q7	Concern for REDD+ (political concern = 1, otherwise = 0)	Q16	Size of private forest (≥ 0.5 ha = 1, otherwise = 0)
Q8	Concern for REDD+ (Indigenous community (IP and LCs) = 1, others = 0)	Q17	Willingness to participate in carbon trade (yes = 1, no = 0)
Q9	What does REDD+ do? (know all 5 major functions = 1, otherwise = 0) [Note: major functions include facilitating reducing the deforestation, reducing forest degradation, promoting sustainable forest management, carbon conservation, and enhancement]	Q18	Primary energy sources for household cooking (fuelwood = 1, otherwise = 0)
		Q19	Willingness to change household cooking energy sources (yes = 1, no = 0)
		Q20	Uses substitute of wood (renewable bioproducts = 1, e.g., Bamboo, rattan, hay, or a combination of them, metals (i.e., non-renewable = 0)

their experiences and expertise. Participants ($n = 136$) were invited based on these criteria, including requirements for at least 33% Indigenous representation, 50% women, and 33% individuals from marginalized communities, aligning with guidelines for community-based forest management in Nepal (Pandey and Pokhrel, 2021). Additionally, each Community Forestry Users Group (CFUG) selected participants who best represented their stakeholder group. Therefore, we assume that they represent the voice of the common people; nonetheless, we cannot guarantee that the internal biases reflected in the selection of participants were completely transparent.

2.2.2. Focus group discussion and key informants' interviews

In addition to the questionnaire interviews, we conducted focus group discussions (FGD) and key informant interviews (KII) at selected sites within the districts using predefined checklists to triangulate the observation gaining more clarity on the topic. Four FGDs were organized: one in Chitwan, one in Saptari, and two in Jhapa districts. Additionally, 27 KIIs were carried out, with nine conducted in each district. These FGDs and KIIs involved stakeholders who had not participated in the questionnaire interviews, ensuring distinct participation in various data collection methods. The participants for the FGDs were selected in collaboration with the REDD+ working group at REDD IC Kathmandu before fieldwork commenced. In Jhapa District, one FGD involved the Indigenous community (Tharu), and another engaged the federation of private forest owners. In Saptari District, an FGD was conducted with the forest-dependent Indigenous community (Musahar), while in Chitwan District, a group consultation was held with the marginalized forest-dependent Indigenous community, specifically the Chepang (Piya et al., 2011), followed by KIIs. Ethical guidelines were strictly adhered to throughout all data collection methods, including questionnaire interviews, FGDs, and KIIs (a sample checklist is available in Supplementary File_S2).

2.2.3. Characteristics of the respondents

The questionnaire interviews encompassed a diverse group of local stakeholders, reflecting various demographic characteristics and professional backgrounds. However, for the quantitative analysis, we exclusively focused on stakeholders who participated in the questionnaire interviews and their responses (Fig. 3). Insights from local stakeholders involved in FGDs and KIIs were not included in the quantitative analysis but were presented in tabular format and discussed in the supplementary information section as applicable.

2.3. Categorization of the variables for statistical tests

The data from the semi-structured questionnaire interviews were categorized into two main themes: dependent variables and independent variables, and then coded to facilitate analysis, as outlined in Table 1. Data not included in these formal statistical analyses were utilized for thematic presentation in tables, figures and discussed in the corresponding section.

2.4. Data analysis

We developed one generic binomial regression model and then nine specific models, each corresponding to a dependent variable as defined in Table 1, to be tested against independent variables also defined in the same table. Details of the analysis and R-codes are provided in a separate file (Supplementary File_S3). The variables were analyzed using a GLM with a 'binomial' distribution and the 'logit' function. The model equation is represented as follows:

$$Y_{ij} = f(a_{ij} + bX_{ij} + e_{ij}) \quad (1)$$

where Y_{ij} refers to the dependent variables (responses) Q1 to Q9 as defined in Table 1; f denotes the function (a binomial distribution with logit function); a_{ij} represents the intercepts of tested models Q1–Q9; b denotes the estimated coefficients for independent variables (predictors); X_{ij} represents the independent variables as defined in Table 1 (district, age, sex, profession, education, and Q15 to Q20); and e_{ij} represents the error terms of models Q1 to Q9. The observed relationships are visually presented through Sankey diagrams. These tests and visualizations were conducted using the R Studio platform with various libraries (R Core Team, 2023).

3. Results

3.1. Understanding REDD and its outreach

The results revealed that 71% of the respondents had previously heard about REDD+. Among them, only 41% had acquired information about REDD+ through mass media, and none had received information from their neighborhoods (Supplementary File_S4). Contrary to our hypothesis, which proposed a uniform understanding of REDD+ knowledge irrespective of social factors, the findings revealed a significant difference ($p < 0.05$) in an understanding of REDD+ knowledge based on gender,

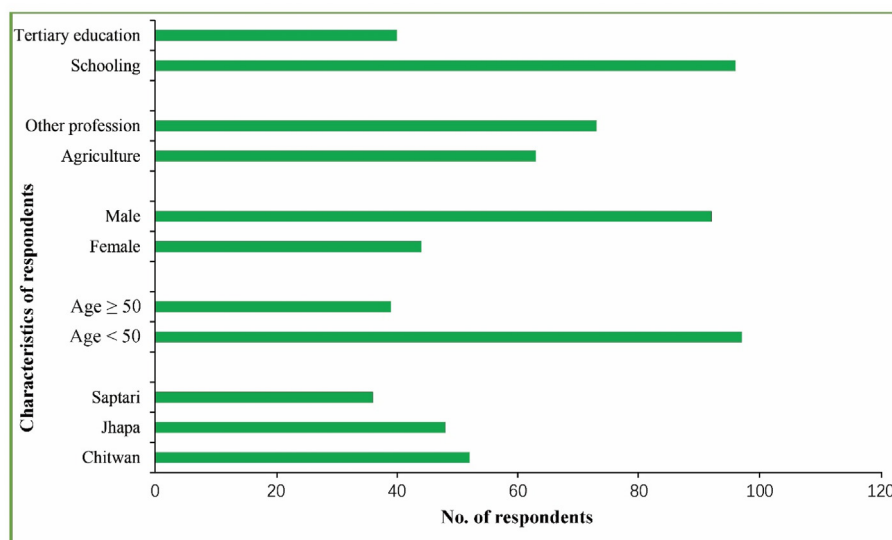


Fig. 3. The proportion of respondents' characteristics belonging to the districts, age group, gender, major profession, and education level.

professional background, and ownership of private forests. Notably, the size of the private forest holding, respondents' willingness to change their household cooking energy strategies, and the utilization of wood substitutes for non-renewable products (mainly metals like iron and aluminum) did not exhibit such variations (Table 2). Therefore, our hypothesis asserting that REDD+ knowledge varies significantly depending on the social characteristics of local stakeholders is rejected. Additionally, the results revealed a significant difference ($p < 0.05$) in understanding REDD+ knowledge between age groups below 50 and those aged 50 and above. The visual relationship between the variables of social possessions under consideration (Fig. 4), and the other key attributes (Fig. 5) is presented using Sankey diagrams.

Similarly, our assumption that university education would provide better exposure to REDD+ knowledge compared to school-level education showed a significant difference ($p < 0.05$) (Table 2). Based on our hypothesis, the Chitwan District should exhibit significantly higher REDD+ understanding; however, we found that both Chitwan and Jhapa districts have similar levels of REDD+ understanding, with a significant difference ($p < 0.05$) compared to Saptari District. Each district faces its unique challenges related to forests, REDD+, climate change, and their interconnections, creating a complex web of issues.

Regarding exposure to REDD+ knowledge through mass media at the local level, the test results showed that such exposure significantly varied ($p < 0.05$) based on factors such as stakeholder affiliations between and within districts, professional backgrounds, willingness to participate in carbon trading, and households using non-renewable construction materials as substitutes for wood, particularly in areas where wood was scarce and/or unaffordable (Table 3).

3.2. Knowledge on understanding relationship between forests and REDD+

Only 29% of the respondents provided a precise response regarding the relationship between forests and REDD+, while a mere 6% demonstrated a good level of familiarity with carbon trading under the REDD+ mechanism (refer to Supplementary File_S4). The test results indicated significant variations in stakeholders' understanding of the relationship between REDD+ and forests based on their professional background and their willingness to change their household energy systems. However, when it comes to understanding whether REDD+ supports carbon trading and economic incentives, the responses significantly differ ($p < 0.05$) based on district of residence, age group, professional background,

willingness to participate in carbon trading, and the primary source of household energy (i.e., firewood) (Table 2). This variation is attributed to factors like the unaffordable price of wood and unstable forest management policies (Table 3).

Regarding the REDD+ mechanism, only a small proportion of local stakeholders (12.5%) were found to be aware of this process, and only a few ($n = 8$) responses indicated that REDD+ directly affects local and Indigenous communities (Fig. 4). Most responses indicated that REDD+ was perceived as the responsibility of the government authority (Supplementary File_S4). The understanding of REDD+'s core objective, particularly its impact on reducing deforestation, exhibited significant differences among stakeholders according to their district of residence, gender, openness to participating in carbon trading, willingness to shift their household cooking energy source, and whether they utilize wood as a substitute for non-bioproducts. These differences may be attributed to factors like unavailability, unaffordability, deforestation, and degradation of forest resources in the locality (Table 3).

3.3. Understanding of REDD+ on other socio-political dimensions

Regarding the potential benefits envisioned by REDD+, only 23.5% of local stakeholders were aware of the major functions of REDD+ (refer to Table 1 for details). Nearly 50% of the respondents were unaware of the potential benefits that may be gained through REDD+ for their local communities and the environment. Additionally, the understanding of REDD+'s capacity to engage in carbon trading from forests significantly differs ($p < 0.05$) among stakeholders based on factors like district of residence, age group, professional background, education level, willingness to participate in carbon trading, use of fuelwood as their primary household energy source, willingness to change their household energy system, and utilization of wood substitutes for nonrenewable construction materials. Moreover, when asked whether REDD+ is a concern for political bodies (Fig. 4), the results showed significant differences ($p < 0.05$) for all the tested variables except in the case of Chitwan District and respondents who use fuelwood as their primary energy source for cooking (Fig. 5). In contrast, when asked whether REDD+ is a concern for Indigenous and local communities, the results indicated significant differences ($p < 0.05$) only regarding the stakeholders' level of education (Table 2, Fig. 5). Qualitative summaries of responses related to REDD+, climate change, and action, forests, and their interrelationships are presented in tabular form (Table 3).

Table 2
Statistical output of the variables under consideration about the REDD + understanding in the study area.

DV	Independent variables													
	Chitwan	Jhapa	Saptari	Age	Sex	Profession	Education	Q15	Q16	Q17	Q18	Q19	Q20	
Q1	0.40 (0.68)	0.09 (0.75)	-3.45* (1.67)	3.43** (1.12)	3.48** (1.16)	-5.45*** (1.10)	-3.19** (1.11)	2.13* (1.01)	-0.66 (1.45)	-0.71 (0.82)	1.33 (0.72)	4.43*** (1.21)	3.35* (1.67)	
Q2	0.47 (0.67)	-1.87** (0.64)	0.09 (0.85)	-0.16 (0.62)	0.74 (0.59)	-2.18*** (0.55)	-0.36 (0.54)	0.75 (0.78)	-1.31 (1.16)	1.73* (0.68)	0.97 (0.56)	0.49 (0.60)	-2.09** (0.78)	
Q3	-0.05 (0.66)	0.01 (0.58)	0.60 (1.20)	0.96 (0.67)	0.46 (0.65)	-2.13*** (0.60)	-0.30 (0.72)	18.37 (1305)	-17.58 (1305)	-0.10 (0.65)	1.07 (0.66)	2.29** (0.71)	-0.84 (1.03)	
Q4	-0.21 (0.81)	0.31 (0.69)	4.53** (1.46)	1.72* (0.76)	-0.48 (0.71)	-1.78** (0.63)	1.17 (0.96)	20.85 (1777)	-19.19 (1777)	-2.56** (0.87)	1.68* (0.82)	4.30*** (1.03)	-4.10** (1.24)	
Q5	0.57*** (0.06)	0.14* (0.05)	0.08 (0.08)	0.02 (0.05)	-0.22*** (0.06)	-0.24*** (0.05)	0.03 (0.05)	0.21** (0.07)	0.20 (0.11)	-0.20** (0.06)	0.01 (0.05)	0.55*** (0.05)	0.08 (0.06)	
Q6	0.80*** (0.06)	0.35*** (0.05)	0.46*** (0.08)	-0.20*** (0.06)	0.01 (0.06)	-0.17** (0.05)	0.16** (0.05)	0.01 (0.07)	-0.02 (0.11)	-0.13* (0.06)	-0.14* (0.06)	0.14* (0.05)	-0.27*** (0.07)	
Q7	0.074 (0.04)	-0.07* (0.03)	0.24*** (0.05)	0.10** (0.03)	0.13*** (0.03)	-0.15*** (0.03)	-0.18*** (0.03)	0.28*** (0.04)	-0.18* (0.07)	-0.17*** (0.03)	0.06 (0.03)	0.20*** (0.03)	-0.27*** (0.04)	
Q8	-0.01 (0.05)	0.04 (0.04)	-0.04 (0.06)	-0.00 (0.04)	-0.01 (0.05)	0.06 (0.04)	0.10* (0.04)	0.06 (0.06)	-0.07 (0.09)	0.01 (0.05)	-0.04 (0.04)	-0.00 (0.04)	-0.00 (0.05)	
Q9	0.05 (0.07)	-0.02 (0.06)	0.38*** (0.09)	0.09 (0.06)	0.21** (0.07)	-0.06 (0.06)	0.01 (0.06)	0.13 (0.08)	-0.08 (0.13)	-0.19** (0.07)	0.03 (0.06)	0.24*** (0.06)	-0.38*** (0.08)	

Note: DV = Dependent variables, symbols (.) = 10%, (*) = 5%, (**) = 1%, (***) = 0.1% significant level, distribution = binomial, link = logit, values presented in the table are estimates and parentheses contain standard errors, **bold figures** represent the significant different at their respective level as described, and the significant level of 5% is considered unless otherwise stated.

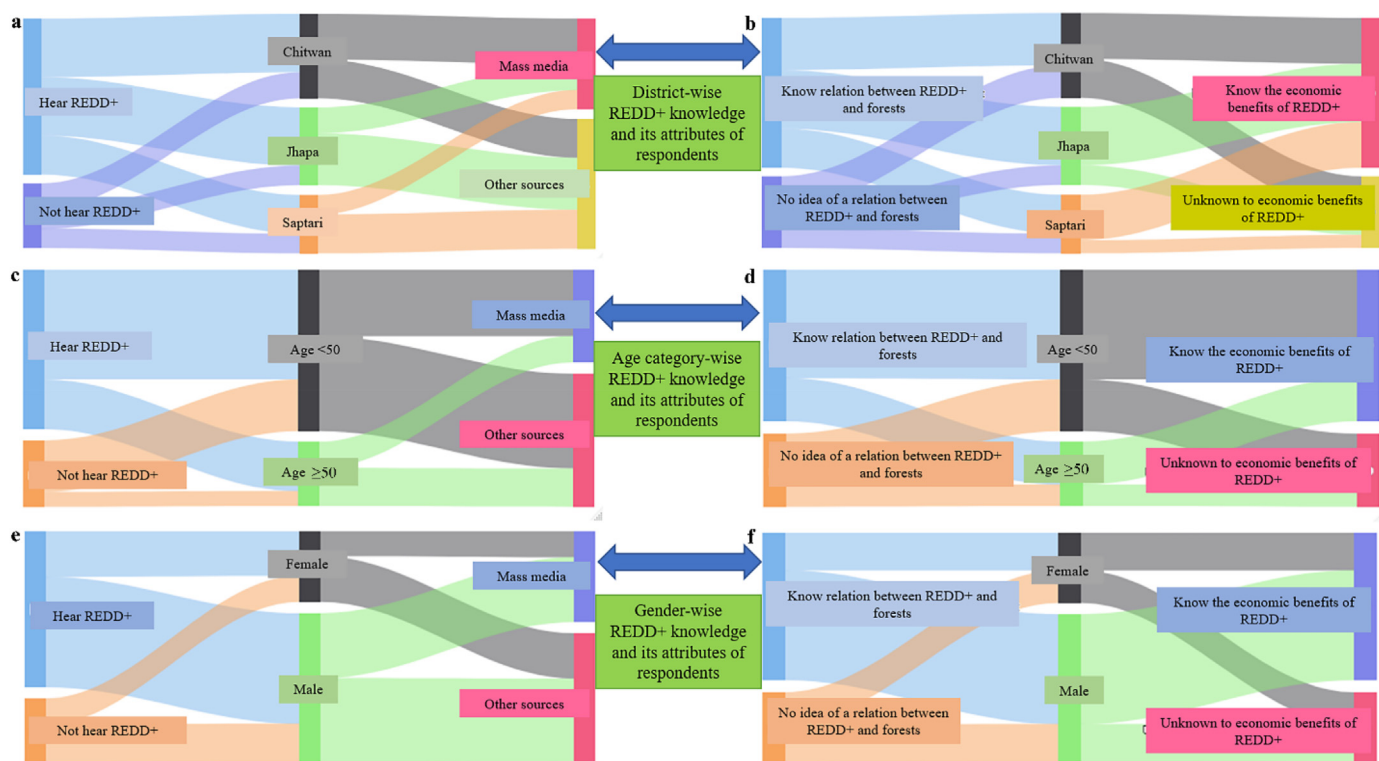


Fig. 4. The Sankey diagrams show a proportional distribution of respondents based on their responses to various dimensions of REDD+ knowledge according to their social attributes across the study area, as defined in Table 1; **a** and **b** represent district-wise REDD+ hearing and knowledge of its relationship with forests; **c** and **d** represent age category-wise (below 50 years and 50 years and above) REDD+ acquaintance and knowledge of its economic benefits; **e** and **f** represent gender-wise REDD+ understanding and its economic benefits perceived across the study areas. Different colors have no meaning other than making the patterns and themes distinct. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

4. Discussion

Local-level engagement of key stakeholders in the implementation and benefit-sharing processes of REDD+ is crucial for ensuring program sustainability. This study assessed the understanding of REDD+ among local stakeholders during the initial stages of REDD+ implementation, focusing on grassroots scenarios in Nepal. Our results identified knowledge gaps between areas where REDD+ pilot activities were implemented and those where they were not. Despite receiving REDD+ readiness funds, the capacity to comprehend and engage with REDD+ processes has not significantly improved. This limited understanding and the observed variations indicate suboptimal implementation of policy actions outlined in international environmental resolutions and national commitments, such as Nepal's nationally determined contributions (Government of Nepal, 2020), Emission Reduction Program Documents (REDD/MOFE, 2018), the National REDD+ Strategy of Nepal (MoF-SC/REDD, 2015), and the National Climate Change Policy (Government of Nepal, 2019). This uncertainty underscores the need for further exploration of issues including marketing, benefit-sharing, governance, and sustainability concerning REDD+ on a local to global scale (Aryal et al., 2024).

4.1. REDD+ -readiness support and knowledge enhancement

The understanding of REDD+ among local stakeholders varies significantly based on their social capital. Our observations are supported by findings from other studies in REDD+ pilot areas (Paudel et al., 2015; Pandit, 2018) which emphasize the socio-economic and ecological attributes related to forest ecosystems and their services (Ostrom, 2009; Pandey et al., 2023). Local stakeholders have expressed concerns about REDD+, viewing it potentially as a threat that could undermine traditional forest-related practices and community rights to forest tenure,

especially for those communities heavily reliant on forests for their livelihoods (Potvin and Mateo-Vega, 2013; Schroeder and González, 2019; Ojha et al., 2019; Cook-Patton et al., 2021). This perception may stem from inadequate understanding and a lack of transparency about the REDD+ approach, or a combination thereof (Kenney et al., 2015; Cadman et al., 2019; Pandey et al., 2020; Pandey, 2021). These findings highlight the importance of considering stakeholders' varying levels of understanding of REDD+ based on their social backgrounds when making future decisions. Meaningful participation of these stakeholders is crucial while implementing fair and equitable benefit-sharing mechanisms for ensuring the smooth implementation of REDD+.

Further, we found that REDD+ readiness efforts, alongside other external support initiatives, have not significantly enhanced stakeholders' understanding and knowledge. For instance, stakeholders in Chitwan District, which received REDD+ pilot project readiness support, did not exhibit significantly different levels of understanding compared to stakeholders in the other two districts without dedicated readiness programs. This could be attributed to the limited spatial and demographic coverage of readiness projects, site-specific activities, and repeated involvement of the same stakeholders. Similar observations were reported in previous studies (Pandey et al., 2014b; Pandey and Pokhrel, 2020) which noted that only 18% of community forests and their user groups were engaged in REDD+ pilot projects in Chitwan District, Nepal. Additionally, Maraseni et al. (2020) identified institutional knowledge gaps and limited ongoing communication and outreach as potential reasons for existing disparities in REDD+ understanding. Introducing overly technical and complex aspects of REDD+ without clarifying the process may not effectively address the urgent challenges posed by climate change (Morita and Matsumoto, 2023; Aryal et al., 2024). Our findings suggest that short-term external support has not significantly contributed to fostering a common understanding of emerging environmental governing mechanisms like REDD+ among

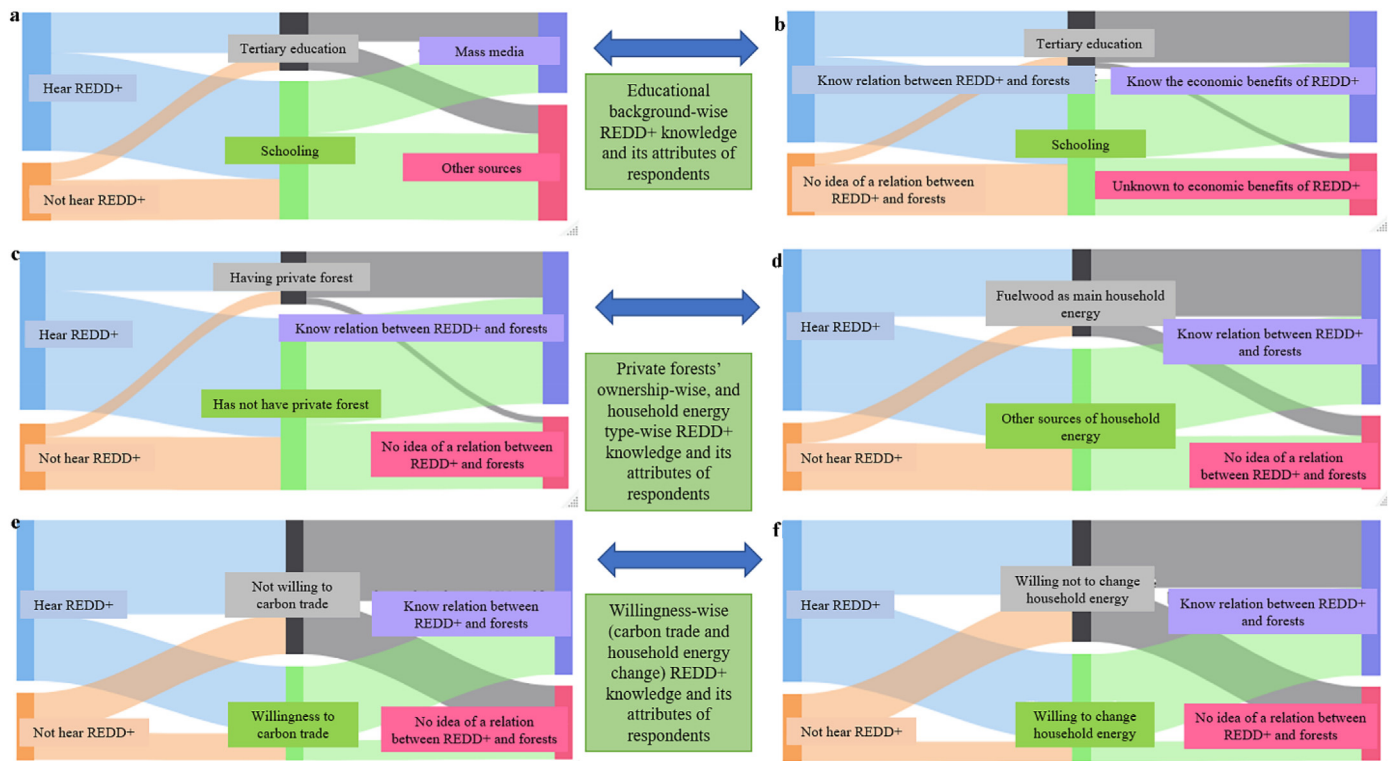


Fig. 5. The Sankey diagrams show a proportional distribution of respondents based on their responses to various dimensions of REDD+ knowledge according to their educational level, private forest ownership, willingness to participate in carbon trading, and the likelihood of changing household energy across the study areas. Figures labeled (a, b, c, d, e, and f) represent the respective proportion of respondents as defined in the text in the middle of the paired diagrams. Different colors have no meaning other than making the patterns and themes distinct. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

local stakeholders. Instead, integrating this new mechanism of climate action into academic curricula and communities' discussion forums is crucial for enhancing local stakeholders' knowledge for better outreach.

4.2. Communication of the REDD+ process at the local level

Our study reveals that inadequate dissemination of the REDD+ program is likely limiting the understanding of REDD+ among key stakeholders at the local level. Only 29% of participants accurately understood the intricate interrelationship between forests and REDD+. This lack of understanding adds complexity to the transdisciplinary nature of REDD+, including institutional and political perspectives related to forest tenure and governance (Lemaitre, 2011; Poudel et al., 2015). Such limited understanding among stakeholders impedes the implementation of REDD+ on the ground in Nepal (Khatri et al., 2012; Khadka et al., 2014; Pandit, 2018). Similar gaps in communication and understanding among stakeholders have been reported globally in other REDD+ countries, such as Lao PDR (Bouthavong et al., 2017), Vanuatu, Fiji, PNG, Pakistan, Bhutan, and Thailand (Maraseni et al., 2020). One possible reason for the poor dissemination of REDD+ knowledge could be the introduction of complex climate discourse and technical jargon, which may pose challenges for ordinary people to understand (Schroeder and González, 2019; Aryal et al., 2024), as observed during FGDs and KIIs as well. Additionally, limited coverage and access in academia and research, inadequate media coverage, insufficient inclusion of local dialects, perception as foreign-driven projects, and lack of frequent interaction and consultation at the local level may contribute to these challenges (Potvin and Mateo-Vega, 2013; Ojha et al., 2019; Cook-Patton et al., 2021). Addressing these persistent issues could minimize knowledge gaps among stakeholders, and facilitate developing a participatory monitoring indicators of forest ecosystem services, especially at the grassroots level (Paudyal et al., 2018), including carbon service and its

co-benefits.

The transmission of new knowledge typically occurs through local communities or neighborhood mechanisms. Surprisingly, our study found that no local stakeholders acquired REDD+ knowledge from their neighborhoods, which contradicts established principles of neighborhood communication (Maude, 2011). Neighborhoods often rely on self-knowledge and peer verification for effective knowledge dissemination (Elwood and Leszczynski, 2013). However, in our study, there was a lack of peer verification or initial knowledge transfer, despite the vision of multi-stakeholder engagement and a participatory approach (Bernard et al., 2014). This may be because REDD+ is an emerging environmental governance that has not yet been fully integrated into local communities, as noted by Mupepi et al., 2014. Consequently, reluctance to adopt new concepts could lead to misunderstandings, erode confidence, or result in incomplete information sharing (Khatri et al., 2012; Mupepi et al., 2014). Adopting effective modes of new knowledge transmission, monitoring and countering the spread of misinformation both online and offline, and leveraging academic platforms to enhance credibility in knowledge dissemination is crucial (Hargreaves, 1999; Paudyal et al., 2015). Implementing extensive outreach policies to educate stakeholders formally and informally could help bridge the gap between policy documents and the realities faced by Indigenous and local communities (Sarmiento Barletti and Larson, 2017).

4.3. Participatory and inclusive REDD+ process

Inclusive REDD+ process serves as a crucial indicator of successful implementation, essential for achieving its intended goals (Weeks and Filardi, 2011; Garnett et al., 2018). Global and local policies emphasize gender-based participation and the rights of Indigenous and local communities in climate-related decisions, including the REDD+ process (Scheba and Scheba, 2017; Aryal et al., 2024) to local policies

Table 3
Summary of qualitative information synthesized from open-ended responses on a questionnaire interviews, FGDs, and KIIs, regarding REDD+ and climate change, connecting forests and the livelihood of the local stakeholders.

Study sites	Situation analysis	Adaptation strategies and expectations analysis
Bagmati Province (Chitwan District)	<p>Forest encroachment, deforestation, and degradation are ongoing, including the reduction of bamboo production due to ruthless harvesting of its culm for consumptive use. The phenology and fruiting habits of Chiuri (<i>Diploknema butyraceae</i>), used in the dowry customs of the Chepang community, have changed. Mustard (<i>Brassia rapa</i>) production has reduced to zero in the locality. Forest cover has increased, the trend of shifting cultivation has decreased, and fallow land has increased. Infestation of alien invasive species, such as <i>Mikania micrantha</i>, in and around the forests has started and proliferated. Infestation of invasive species (e.g., <i>Eupatorium species</i>) has led to the disappearance of non-timber forest products (NTFPs). There is an increase in the frequency of disease infestations in potatoes. Negative human-wildlife interactions have increased in recent decades. The Scaly-breasted Munia has disappeared from the area, and the Eurasian Dove (<i>Streptopelia decaocto</i>) has started early hatching and brooding. There is a desire to include protected areas and biological corridors under the REDD + carbon trading mechanism, particularly among the local community of Chitwan District. Pressure on forests for energy sources has reduced due to the availability of firewood alternatives and shifting livelihood options from agriculture to service-oriented activities.</p>	<p>Market-based imported products are used as substitutes for wood in construction, highlighting the imminent need to address the drivers of deforestation and degradation through sustainable forest management based on production. There is a search for alternative livelihood options beyond forest-based strategies, such as shifting cultivation, particularly among the Chepang community. Support has been received from various organizations to enhance social and livelihood security in our community (the Chepang). Market-driven products have started to replace mustard products. There are initiatives for fodder and other tree plantations on private lands, fallow lands, and public lands. Concerns are raised about benefiting from REDD+ projects due to the infestation of invasive species and trends toward forest degradation. There is a reduction in the area dedicated to potato farming. There is a desire for wildlife-proof fencing and alternative cropping systems. There is a call for the conservation of threatened species of animals and birds under the umbrella of REDD+ and climate action in forest ecosystems. Additional REDD+ benefits are sought for Chitwan because the area also protects rhinos and tigers, which comprise a significant portion of forest-related options. Continuous support for REDD+ readiness is required. Local stakeholders seek carbon trading benefits, emphasizing their longstanding protection of forests since ancient times. Exploration of environmentally friendly and economically viable household energy sources is encouraged. Addressing the drivers of deforestation and degradation and promoting private plantations with an interest in participating under the REDD+ mechanism, particularly private forest owners. Clear guidelines are needed to introduce species and facilitate sustainable forest management to promote conservation through the sustainable use of natural resources such as forest</p>
Koshi Province (Jhapa District)	<p>Forest cover has been lost and decreased due to social, developmental, and climatic factors. An exotic species, <i>Paulownia species</i>, has been introduced. Red bears have been observed, but vultures have disappeared from the locality. Asian Koels (<i>Eudynamys scolopaceus</i>) are singing earlier, but mynas (<i>Acridotheres tristis</i>) and swallows have disappeared.</p>	<p>Addressing the drivers of deforestation and degradation and promoting private plantations with an interest in participating under the REDD+ mechanism, particularly private forest owners. Clear guidelines are needed to introduce species and facilitate sustainable forest management to promote conservation through the sustainable use of natural resources such as forest</p>

Table 3 (continued)

Study sites	Situation analysis	Adaptation strategies and expectations analysis
	<p>There is a deficit of timber for construction, and it is unaffordable if available. Fetching water has become more time-consuming due to the drying out of nearby springs in the village. Species composition has changed due to monoculture plantations and the invasion of invasive and alien species in the area. There has been an increase in negative interactions between elephants and humans. People own private forests on their private land and have formed an association of private forest owners in the district. Iron, aluminum, sun mica, or imported alternatives are being used as options for wood products. The community has joined the community water supply system, paying tariffs. There are multiple uses of water, including ditches near water sources for wastewater collection, where wildlife is frequently observed.</p>	<p>ecosystem goods and services. Climate actions, including REDD+, are necessary to mitigate the impacts of climate change, preserve biodiversity, and ensure social security by exploring nature-based solutions. Shifting from agricultural farming to tree planting in farmland can reduce negative interactions between people and wildlife. Resettlement plans for human residences are required away from traditional nomadic wildlife paths, especially for elephants. Adoption of diversified cropping systems is essential. Solar fencing has been constructed to reduce human-elephant interactions. There is an increasing willingness to participate in REDD+, considering the trees in stakeholders' farmlands and private forests. Improving forest management mechanisms and marketing its products are essential. Implementing carbon trading and the REDD+ mechanism in private forests is crucial. Subsidies and grants are needed to facilitate easier harvesting and access to water resources, including rainwater and groundwater harvesting. Bamboo products are increasingly being used. Cattle dung is used for household energy supply due to the scarcity of fuelwood or the unaffordability of cleaner energy sources, particularly in the Musahar ethnic and Indigenous community. Plantation programs are being promoted in public and private abandoned areas. Cropping patterns are shifting from irrigation-intensive to rain-fed (paddy, sugarcane, tobacco, fallow). There is a growing increase in plastic products and infestation of invasive species in barren areas. Also, research on forest health, including pests and pathogens, is required. Sustainable wildlife management through regulated harvesting is needed for proliferated species, with conservation initiatives required for vulnerable and endangered species. There is a need to streamline forest management mechanisms and marketize forest products. Implementing the carbon trading and REDD+ mechanisms in private forests is also essential. Hill recreational parks are</p>
Madhesh Province (Saptari District)	<p>Difficulties in finding nearby forests to villages. The Hadjora (<i>Oroxylum indicum</i>) has disappeared. Infestation of disease in Sissoo trees has led to their death. Banning the harvest of trees from forest areas has increased the cost of wood in the market, prompting a shift to alternatives such as iron and aluminum. Water scarcity is increasing, especially for irrigation purposes. <i>Shorea robusta</i> trees are infested with disease, causing wilting and die-back. Natural forests of Sissoo and Khayar (<i>Acacia catechu</i>) have disappeared. Wildboar and Nilgai (<i>Boselaphus tragocamelus</i>) are proliferating, while wild-water buffalo, tiger, and brown bear populations are sparse. There is limited availability of firewood, leading to an increased tendency to switch household energy sources in recent decades. There has been an increase in fire incidents. There is a desire to switch from household energy sources like cow dung to cleaner alternatives that are currently</p>	<p>ecosystem goods and services. Climate actions, including REDD+, are necessary to mitigate the impacts of climate change, preserve biodiversity, and ensure social security by exploring nature-based solutions. Shifting from agricultural farming to tree planting in farmland can reduce negative interactions between people and wildlife. Resettlement plans for human residences are required away from traditional nomadic wildlife paths, especially for elephants. Adoption of diversified cropping systems is essential. Solar fencing has been constructed to reduce human-elephant interactions. There is an increasing willingness to participate in REDD+, considering the trees in stakeholders' farmlands and private forests. Improving forest management mechanisms and marketing its products are essential. Implementing carbon trading and the REDD+ mechanism in private forests is crucial. Subsidies and grants are needed to facilitate easier harvesting and access to water resources, including rainwater and groundwater harvesting. Bamboo products are increasingly being used. Cattle dung is used for household energy supply due to the scarcity of fuelwood or the unaffordability of cleaner energy sources, particularly in the Musahar ethnic and Indigenous community. Plantation programs are being promoted in public and private abandoned areas. Cropping patterns are shifting from irrigation-intensive to rain-fed (paddy, sugarcane, tobacco, fallow). There is a growing increase in plastic products and infestation of invasive species in barren areas. Also, research on forest health, including pests and pathogens, is required. Sustainable wildlife management through regulated harvesting is needed for proliferated species, with conservation initiatives required for vulnerable and endangered species. There is a need to streamline forest management mechanisms and marketize forest products. Implementing the carbon trading and REDD+ mechanisms in private forests is also essential. Hill recreational parks are</p>

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Table 3 (continued)

Study sites	Situation analysis	Adaptation strategies and expectations analysis
	<p>unaffordable. Incidents of asthma and eye strain have increased among people, leading to more frequent consumption of sugarcane, fresh juice, watermelon, and yogurt. Economic options in rural areas are very limited.</p>	<p>being promoted to provide cool and fresh air during the summer. Deep tube wells are being constructed for irrigation and domestic water use, along with the establishment of rainwater harvesting ponds across forests and public lands to recharge groundwater quickly and utilize it for bushfire control. Fire preventive measures are widely needed. Diversification of economic and livelihood options is crucial for rural Indigenous communities in the changing socio-environmental context.</p>

(GoN/MoFE, 2021; Pandey and Pokhrel, 2021). However, our study (Supplementary File_S4) identified a low level of gender-based participation and a poor understanding of REDD+ concerns among local and Indigenous peoples, particularly challenging for women from marginalized communities and stakeholders from Indigenous groups like the Chepang, Tharu, and Musahar communities in our study areas. Similar findings have been reported in other REDD+ countries, highlighting disparities in gender-based involvement (Poudel et al., 2015; Tiani et al., 2015; Skutsch and Turnhout, 2020; Pham et al., 2021a, 2021b). Our observations underscore a significant gap between policy intentions and on-ground practices, emphasizing the urgent need to enhance participation and engagement among marginalized populations, including women and vulnerable forest-dependent communities, as outlined in national and global policy documents (REDDIC, 2016; Duchelle et al., 2018; Aryal et al., 2024). Drawing on Nepal's community forestry program, which mandates gender parity in decision-making bodies within community forest users' groups, can serve as a model for promoting gender-based participation and inclusive policies (Paudyal et al., 2015). This includes ensuring proportional representation from local marginalized, ethnic, and Indigenous communities, tailored to local contexts (Government of Nepal, 2018; Pandey and Pokhrel, 2021).

We found that local-level REDD stakeholders (LLRS) strongly believe that integrating private forests into carbon credits could enhance forest product marketing governance, a longstanding issue in REDD+ countries, including Nepal (Paudel et al., 2015; Maraseni et al., 2019; Pandey et al., 2024). Poor governance in managing forest ecosystems for multiple uses, including climate actions, is exacerbated by cumbersome regulatory procedures and overlapping jurisdiction issues (Amatya and Lamsal, 2017). In response to contemporary environmental and social challenges related to forest ecosystems, promoting private forests on fallow and marginal lands could offer a promising strategy. This approach aims to alleviate pressure on national forests, stimulate local and national economies, and optimize forest resource utilization without compromising the customary rights of local and Indigenous communities concerning social and REDD+ concerns. However, the high transaction costs, technical complexities, and intricate accounting systems associated with carbon credits in the REDD+ process pose additional burdens on local stakeholders, especially private forest owners (Amatya and Lamsal, 2017; Pandey and Pokhrel, 2020; Morita and Matsumoto, 2023). A participatory forestry policy process could potentially enhance forest governance and navigate towards a win-win situation for sustainable forest management (Paudyal et al., 2019). This approach is challenging but considered essential in addressing contemporary social and environmental challenges related to forests.

Meaningful participation of multi-stakeholders in the REDD+ process is crucial for its sustainability. It facilitates addressing grievances

(Paudyal et al., 2018; Skutsch and Turnhout, 2020), ensures effective program implementation (Khatri, 2018), and aligns with international principles under the UNFCCC (Paudyal et al., 2020). Active engagement of local-level stakeholders in technical matters is also essential (Kenney et al., 2015), as outlined in the Cancun Safeguards Framework for REDD+ stakeholder engagement (FAO, 2015). Nepal, as a pioneering country in REDD+ piloting at the local level, shares its experiences globally and offers valuable lessons learned from ground-level implementation. Despite meeting the prerequisites of the Warsaw Framework and ranking among the top recipients of REDD+ funding (Maraseni et al., 2019, 2020), challenges persist in engaging stakeholders and enhancing their understanding of REDD+ (Weeks and Filardi, 2011; Garnett et al., 2018). To maintain Nepal's leadership and accelerate progress towards performance-based carbon credits, bridging knowledge gaps and providing insights into ground realities are imperative.

Overall, this study stands out for several reasons: Firstly, it adopts a well-established participatory research approach to capture the perspectives of local-level REDD+ stakeholders. Secondly, it provides insightful comparisons between pilot project areas and non-project areas within similar socio-ecological landscapes, informing climate-related policy decisions concerning forests. Thirdly, it explores the implications of REDD+ on local, marginalized, and Indigenous communities, alongside diverse stakeholder engagement and their understanding of REDD+ processes. This includes mainstreaming these insights into real REDD+ implementation and realizing benefits through carbon credits, emphasizing fair and equitable benefit-sharing mechanisms within Nepal—a globally representative REDD+ country. Further, our findings contribute to expanding the understanding of social-ecological systems (SES) theory in the context of REDD+, linking forest ecosystems (resource system) to institutional decision-making (resource governance) for climate action. However, we acknowledge limitations in our study, such as the selection of interview participants limited to three districts, which may impact the generalizability of our results. Future research with a larger sample size encompassing broader spatial and socio-ecological landscapes could be instrumental in enabling deeper exploration of various dimensions of REDD+, including economic and financial analyses of REDD+ projects, understanding benefit-sharing mechanisms, and examining social, ecological, and climate justice perspectives. Nevertheless, the findings from this study provide valuable lessons for future policy development, aiding in assessing REDD+ progress on the ground and formulating strategies to mainstream benefit-sharing mechanisms effectively. This study serves as a reference for enhancing the REDD+ process in climate-related decision-making forums, contributing differentiated actions to address the global environmental crisis of climate change while addressing social concerns.

5. Conclusion

The engagement of local stakeholders in the REDD+ implementation and benefit-sharing process is crucial for the program's sustainability. This study assessed understanding of REDD+ in local stakeholders in Nepal, highlighting the knowledge gaps between areas where REDD+ pilot activities were implemented and those where they were not. Despite receiving REDD+ readiness funds, stakeholders' capacity to comprehend the REDD+ process has not significantly improved. This limited understanding indicates suboptimal implementation of policy actions agreed upon in international environmental resolutions and national commitments. Further, the study revealed that knowledge and understanding of REDD+ vary among local stakeholders based on their social capital. Some stakeholders perceive REDD+ negatively, fearing it could jeopardize traditional forest-related practices and community rights. The study recommends that future decisions consider stakeholders' social backgrounds, their voices and choices to facilitate the smooth implementation of REDD+ and instrument its equitable benefit sharing mechanisms. Moreover, previous REDD+ readiness efforts have not significantly enhanced stakeholders' knowledge. For instance, in Chitwan, where

REDD+ pilot projects were implemented, stakeholders' understanding was not significantly different from those in districts without such projects. Additionally, poor communication and outreach have hindered the dissemination of REDD+ knowledge, contributing to a limited understanding of the program among local stakeholders. The study emphasizes the need for affirmative action on outreach and knowledge dissemination to improve understanding of this emerging environmental governance mechanism.

The study also emphasizes the importance of participatory and inclusive REDD+ processes. Gender-based participation and the inclusion of Indigenous and local communities in climate-related decisions are crucial for achieving REDD+ goals. However, the study observed low levels of participation and understanding among these groups. Result suggests acknowledging both the adaptation and mitigating roles of forest ecosystems while improving forest governance and adopting participatory forestry policies for climate justice and social sustainability. Overall, the study underscores the need for better knowledge dissemination, inclusive stakeholder engagement, and participatory policies process to ensure the successful implementation of REDD+ and its benefit-sharing mechanisms before it is too late. The findings provide valuable insights and can serve as a reference for future policy development and climate-related decision-making in REDD+ countries, including Nepal and beyond.

Data availability

The data will be available upon reasonable request to the corresponding author.

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Conflict of interest

The authors declare that there are no financial or other conflicts of interest among the authors, supporting organizations regarding the data used, or any other issues related to this research.

CRedit authorship contribution statement

Hari Prasad Pandey: Writing – original draft, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Tek Narayan Maraseni:** Writing – review & editing, Supervision. **Armando Apan:** Writing – review & editing, Validation, Supervision. **Shreejana Bhusal:** Writing – review & editing, Methodology, Data curation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.fecs.2024.100239>.

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