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Climate Change Adaptation by Smallholder Tea Farmers: a Case Study of Nepal

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Highlights:

1. Most tea farmers in Nepal are aware of climate change and how to adapt to it.
2. Common adaptation strategies are crop diversification, soil conservation, agroforestry, and the usage of less climate-sensitive tea cultivars.
3. Farmers who are members of a cooperative, who have access to credit, and who attended frequent training generally used a wider range of climate change adaptation strategies.
4. Many tea farmers are not aware of the government's strategic plans to increase the production and export of Nepalese tea.

Climate Change Adaptation by Smallholder Tea Farmers: a Case Study of Nepal

Abstract

Climate change is threatening the livelihood of tea farmers in Nepal. Simultaneously, the production of tea is becoming an increasingly important economic sector for the country. This study aimed to reveal the adaptation behavior towards climate change among smallholder tea farmers, particularly which demographic, institutional, and information source factors are likely to influence the degree of adaptation. We collected quantitative data in the district of Ilam via 91 farmers through a questionnaire survey and applied descriptive statistics, multiple regression, and binary logistic regression models to analyze the collected data. Findings revealed that information sources (peer exchange, internet, and training attendance), as well as institutional factors (cooperative membership and credit access), positively influenced the degree of climate change adaptation among the respondents. Easier credit access and joining cooperatives could enhance the adaptative capacity of smallholder tea farmers. Improving the interaction between the Nepalese government and stakeholders involved in the domestic tea value chain could also increase economic success.

Keywords: Climate Change, Adaptation Strategies, Smallholder farmers, Tea Production, Nepal

1. Introduction

The impacts of climate change on the agricultural sector are increasing (Duncan et al. 2016), not only for staple crops but also for cash crops. Many high-value cash crops such as wine, coffee, or tea are particularly sensitive to a changing climate (Mozell & Tach 2014). Thus, climate change will impact the supply of many popular beverages in addition to food security. For example, climate-induced harvest losses of barley would reduce the supply of beer (Xie et. al 2018). Similarly, the future of global wine production might not be secured without appropriate climate change adaptation (Hannah et al. 2013). This need for adaptation also holds for non-alcoholic beverages. An increase in extreme weather events due to climate change would lead to higher harvest losses in tea production in the future (Ahmed et al. 2014).

The IPCC Special Report on Climate Change and Land highlights that climate change poses a global threat to food security with a high impact on the developing world (Mbow et al. 2019). Reduced crop yields and harvest losses due to climate change will have a large effect on smallholder agriculture systems (Beltrán-Tolosa et al. 2020). These systems consist of farmers whose livelihood is largely dependent on agricultural production. Smallholder farmers face a higher risk of poverty and food insecurity due to the high dependence on their crops and livestock (Morton 2007). Additionally, limited information as well as financial constraints contribute to the socio-economic instability of smallholder farmers while they are facing the negative impacts of climate change (Sietz et al. 2012). This observation holds both for smallholder staple and cash crop farmers.

The tea (*Camellia sinensis*) sector is growing in various parts of the world. For example, tea production has increased by more than 60% between 2004 and 2014 in Nepal (ITC 2017). This growth is proof of an increasing share of regional livelihood being generated through tea production. The Nepalese tea sector largely consists of smallholder farmers who are highly dependent on tea production as their main source of income. However, Nepal´s tea industry is also impacted by climate change as are most other agricultural fields around the word (Chalise et al. 2017). As the government of Nepal aims to increase production and export of tea, it should be a natural consideration to gain insight into the industry's climate change adaptation behavior (ITC 2017). This is not only important from an economic viewpoint but primarily for the development of effective policies.

A lack of awareness regarding climate-smart agriculture leaves farmers more exposed to any potential losses. Inappropriate adaptation also lowers overall agricultural productivity (Woods et al. 2017). Therefore, many studies have investigated how the international tea industry is adapting to climate change. These studies are however primarily focused on small and large tea farms in countries with a higher volume of tea production, such as India (Biggs et al. 2018a), China (Ahmed et al. 2014), Vietnam (Nguyen & Mitsumasu 2016), Japan (Ashardiono & Cassim 2014), Kenya (Ochieng et al. 2016), and Sri Lanka (Gunathilaka et al. 2018). Research focusing on climate change adaptation behavior of smallholder tea farmers in tea producing countries with a lower production volume, like Nepal, is still missing.

To fill this gap, we conducted an empirical study among smallholder tea farmers in Nepal. The aim was to provide insight into the current situation and the identification of factors which positively influence the adaptation behavior of the tea farmers by answering the following research questions:

1. How aware are Nepalese tea farmers about climate change?
2. Which strategies are applied by smallholder tea farmers in Nepal to adapt to climate change?
3. How do socio-demographic, farm and institutional characteristics, as well as information sources influence the implementation of adaptation strategies?

2.Theoretical background

2.1 The tea sector of Nepal

Tea production in Nepal dates back to the year 1863 when local farmers started to become aware of the commercial potential of tea after taking notice of the already thriving tea farming sector in neighboring Darjeeling (India). While currently only being in the 19th position among all tea producing countries in terms of production quantity, tea continues to be an increasingly important driver of economic growth in Nepal (ITC 2017). The current state of Nepalese tea production can be classified into two major tea processing methods: (i) Crush, Tear, Curl (CTC), and (ii) orthodox processing. The CTC method is focused on producing large volumes of lower quality tea, mostly for domestic consumption or the export to neighboring countries, particularly to India. Orthodox processing is more complex and time-consuming, resulting in a higher quality product that is being sold as loose specialty tea around the world (NTCDB 2018). Most of the smallholder farmers in the study area are exclusively involved in the orthodox tea value chain. Directly after harvesting, farmers sell the tea leaves to surrounding tea factories for further processing. As pointed out by the export strategy for Nepalese tea (ITC 2017), a focus on orthodox tea is the key driver to successfully promote it in the most important export markets, e.g. Germany.

2.2 Climate-smart Agriculture

Climate-smart agriculture (CSA) aims to facilitate actions towards the transformation of agricultural systems to thrive in shifting climate patterns (FAO 2020). Many CSA response options provide climate adaptation and mitigation synergies with other co-benefits, including livelihood and biodiversity conservation (Rosenzweig et al. 2020). The three core pillars of CSA can be defined as (i) sustainability in productivity and standard of living, (ii) a focus on climate change adaptation, and (iii) the reduction of greenhouse emissions. While food security is a top priority within this context, CSA can equally be applied to non-food agricultural systems. Improved adaptation to climate change leads to a better economic outlook, which has a positive effect on the overall wellbeing of society. Many studies have investigated factors that influence the degree of adaptation of CSA, as well as the most common constraints among affected communities. Access to credit, information provision, and education on farming practices are considered as key conditions for successfully integrating CSA (Makate et al. 2019). However, these conditions are often not applied appropriately, which is why farmers in developing countries simultaneously perceive them as the main constraints for climate change adaptation (Tsige et al. 2020; Nalau et al. 2018). Therefore, the adoption rate of CSA in developing countries remains relatively low while CSA is becoming an increasingly important concept (Amadu et al. 2020b). Nepal´s agricultural production can be increased and made climate-resilient by implementing CSA approaches (CGIAR 2017). These approaches include but are not limited to improved access to credit and information. We apply this CSA framework of the CGIAR to understand the degree of climate change adaptation among the smallholder tea farmers of Nepal.

2.3 Diffusion of Innovations

The theory of diffusion of innovations explains why and at which rate certain ideas or innovations spread within a society (Rogers 2003). Innovations are not adopted by individuals all at the same time (Infante et al. 1997). Adopters can thus be categorized into several groups, indicating at which stage they tend to adapt to a new behavior/innovation: (i) innovators, (ii) early adopters, (iii) early majority, (iv) late majority, and (v) laggards. The categorization of an individual depends on the degree and the stage when innovations are adopted. Applying this idea to the adaptation process in CSA, Long et al. (2019) identified that ineffective policies and naturally reluctant users (farmers) can shift the diffusion of innovation towards later stages of the adoption process. These logical steps of adoption are initiated by awareness and knowledge on the subject. We therefore investigated the awareness of tea farmers regarding climate change to see if the knowledge on this topic potentially influences the degree of adaptation. Climate change challenges the applicability and development of agricultural models due to its unpredictability (Kipling et al. 2019). As a logical consequence, the expressive power and applicability to policymakers remain limited. Based on this problem, we attempted to detect the actual perception and behavior of the tea farmers in Nepal by comparing literature induced findings with the actual responses given by the sample. This method aimed to uncover if commonly accepted adaptation strategies in tea farming were also used by smallholder tea farmers in Nepal.

2.4 Climate change adaptation in tea farming

Different adaptation strategies are implemented in tea farming to build climate resilience (Figure 1). These factors were derived from research focused on climate change adaptation in various agricultural fields, including tea farming. In this study, we used the adaptation strategies to see which of them are applied by tea farmers in Nepal within the context of climate change. The most common strategies include the usage of more climate-resilient tea cultivars (Biggs et al. 2018a; Fahad and Wang 2018) as well as soil conservation connected to adjustments in the usage of fertilizers, pesticides, and irrigation (Deressa et al. 2009; De Sousa et al. 2018; Biggs et al. 2018a). Agroforestry is an equally common adaptation measure in tea farming, by protecting tea plantations from extreme weather and leading to a positive effect on yields and the living situation (Bedeke et al. 2018; Amadu et al. 2020a). Additionally, the creation of awareness programs and smart controls for the usage of pesticides and fertilizers can improve adaptive farming approaches (Biggs et al. 2018a; Shi-yan et al. 2018). Furthermore, irrigation, water conservation, and the prevention of deforestation are equally relevant coping strategies for the farmers. Another common measure to lower the risk of potentially negative effects of climate change on tea farmers is crop diversification on the farm (Menike & Arachchi 2016; De Sousa et al. 2018; Fahad and Wang 2018, Shi-yan et al. 2018). Most farmers tend to allocate their land not exclusively to tea, but also to grow further crops for their consumption or sale.

2.5 Factors influencing climate change adaptation in agriculture

Various factors influence the adoption rate of different adaptation strategies. They can be grouped into institutional characteristics, socio-demographic aspects, farm characteristics, and information access (Figure 1). Based on previous literature, the most prevalent factors have been identified and were used as independent variables for further analysis in this study. Socio-demographic aspects are basic characteristics of the farmers which potentially influence their adaptation behavior. These include household size, education, training participation, age, and gender (Trinh et al. 2018; Shi-yan et al. 2018; Makuvaro et al. 2018; De Sousa et al. 2018; Arbuckle Jr. et al. 2013). Similarly, farm characteristics such as farm size and the elevation of the farms affected the farmers' adaptive capabilities (Sahu and Mishra 2013; Ali and Erenstein 2017; Bedeke et al. 2018; Gunathilaka et al. 2018). Institutional characteristics, particularly the access to credit and cooperative membership had positively influenced the farmer’s adaptation behavior in previous studies (Trinh et al. 2018; Menike & Arachchi 2016; De Sousa et al. 2018). This also holds for access to information via various media sources and training through the provision of extension services (Trinh et al. 2018; Shi-yan et al. 2018; Ali & Erenstein 2017; Gunathilaka et al. 2018).

Adaptation strategies in tea farming

- **Crop diversification** (Menike & Arachchi 2016; De Sousa et al. 2018; Fahad and Wang 2018, Shi-yan et al. 2018)
- **Rain water storage** (Menike & Arachchi 2016; Fahad and Wang 2018)
- **Water conservation with ponds** (Nguyen and Mitsumasu 2016; Fahad and Wang 2018, Shi-yan et al. 2018)
- **Soil conservation** (Deressa et al. 2009; De Sousa et al. 2018; Biggs et al. 2018a)
- **Less climate sensitive cultivars** (Biggs et al. 2018a; Fahad and Wang 2018)
- **Agroforestry** (Bedeke et al. 2018; Amadu et al. 2020a)

Factors influencing adaptation

- **Institutional characteristics: access to credit, cooperative membership** (Trinh et al. 2018;Menike & Arachchi 2016;De Sousa et al. 2018)
- **Socio-demographic aspects: age, gender, education** (Trinh et al. 2018;Shi-yan et al. 2018;Makuvaro et al. 2018;De Sousa et al. 2018;Arbuckle Jr. et al. 2013)
- **Farm characteristics: size, farm elevation**(Sahu and Mishra 2013;Ali and Erenstein 2017;Bedeke et al. 2018;Gunathilaka et al. 2018)
- **Information access: media sources, trainings** (Trinh et al. 2018;Shi-yan et al. 2018;Ali & Erenstein 2017;Gunathilaka et al. 2018)

Figure 1: Adaptation strategies and factors influencing the degree of adaptation

3.Methodology

3.1 Study area

Jhapa (18.3 million kg) and Ilam (4.15 million kg) were the two major tea-producing districts of Nepal in 2018 (Figure D 1). Ilam district has the highest number of smallholder farmers (6,985) (NTCDB 2018). As our study is focused on smallholder tea farmers, Ilam was the most feasible district in terms of accessibility and reaching the targeted research population. The research area has a total size of 1,703 km^2 and inhabits around 303,000 people (City Population 2017). It is divided into a total of ten municipalities (Figure D2). Out of these ten, three municipalities were selected for this study: Ilam, Suryoday, and Deumai. These municipalities covered the entire district from west to east and allowed the attainment of representative data for the whole district.

3.2 Climate in the study area

Due to its topographic variation, Ilam district experiences large differences in weather according to the climate zones (Table B). The most common climatic conditions can be defined as subtropical with an elevation between 1,000 to 2,000 meters. This range covers approximately 40.1% of the total area of Ilam district. It is noteworthy that between 1,000 to 2,000 meters was also the elevation range of all tea farms participating in this study. Climate data for Ilam shows that a large share of the annual precipitation occurs during June, July, August, and September (Climate data 2019). Precipitation patterns in Ilam district are strongly influenced by the yearly monsoon season. A shift towards higher unpredictability of the monsoon in Nepal is expected to happen (Malla 2008). The climate trend analysis of Nepal from 1971 – 2014 reveals a shift in temperature and annual precipitation for all districts of the country (DHM 2017). Looking at the specific climate development for Ilam district, DHM (2017) reveals a trend of increasing temperatures for all seasons while annual precipitation is expected to decrease by up to 10 mm. Pre-monsoon precipitation trends for Ilam district show a slight increase in rainfall while monsoon precipitation is expected to decrease significantly. As in other parts of Nepal, the variability of monsoon rains in Ilam district is also expected to increase (World Bank Group 2020). Ilam district has to cope with more unevenly spread rainfall, longer drought and wet periods, and the occurrence of floods (Lillesø et al. 2005). These climatic conditions are already stressing local agriculture in the area and are expected to increase in the future. As tea farming in Ilam is dependent on natural irrigation, the combination of increasing temperature and decreasing annual precipitation could become a serious threat to domestic tea production. Heavy rainfall over a longer period can cause additional threats for tea farmers, such as blister blight disease. This parasitic fungus thrives in humid environments and can cause dramatic harvest losses for tea farmers (Sen et al. 2020).

3.3 Data collection

Primary data was collected using a structured questionnaire (Appendix A). It was developed based on the theoretical background presented in Section 2. The formulation and content of the questionnaire were inspired by a recent study on reduced tillage practices (Bavorová 2020). Further inspiration for the development of relevant questions was taken from related studies referred to in Figure 1. Additionally, the survey content was adjusted to cultural and regional specifics based on other publications focusing on the same study area, e.g. from Karki et al. (2011). The questionnaire was primarily designed to identify how many and which specific climate change adaptation measures were used by the farmers. Besides the socio-demographic characteristics of the respondents, we asked which specific information sources they use for educating themselves about tea cultivation practices and climate change. For the analysis it was important to know if credit access and cooperative membership have a positive influence on adaptation behavior. Therefore, questions connected to institutional variables have been included as well. The questionnaire was divided into categories with a total of 23 questions:

1. **Climate change perceptions and adaptation strategies** (climate change awareness, perceived impact on farming performance, adaptation strategies, constraints of adaptation)
2. **Financing and information access** (use of loans, sources of weather and tea cultivation information, participation in training, awareness of tea export strategy, membership in cooperatives, the relevance of information)
3. **Sociodemographic characteristics** (education, age, experience in tea farming, farm size & elevation, HH size, workforce distribution, other crops on the farm)

Data was collected in September 2018 by using exponential non-discriminative snowball sampling. This method allowed access to hidden populations while being cost and time efficient (Dudovsky 2018). After close interaction with the main contact in the study area, several referrals were provided in other municipalities to get a representative image of Ilam district. Access to the farmers was gained through several contacts in the district who provided us with further references of tea farmers in Ilam. An assistant from a local university was hired to support us in conducting the interviews with the farmers and with translating the conversations and responses to the posed questions. All questionnaires were filled out in paper form based on individually appointed face-to-face interviews with the farmers. The questionnaire was translated from English to Nepali before the field research. After piloting the survey among several field experts before the data collection, unclear questions and translation errors were amended and adjusted accordingly. A total of 91 respondents were interviewed during the field research. 28 interviews were completed in the Ilam municipality, 20 in Deumai, and 43 in Suryoday.

3.4 Data analysis

3.4.1 Selection of variables

Table 1 includes all dependent and independent variables based on the theoretical background presented in Section 2. The number of adaptation strategies used by the farmers was defined as the dependent variable. Furthermore, two out of the six adaptation strategies (agroforestry and climate-resilient cultivars) for analysis have been identified. They were taken from the questionnaire section where farmers were asked to indicate the climate change adaptation strategies they are already applying (Appendix A). The share between farmers using/not using agroforestry as well as climate-resilient cultivars was relatively balanced. Therefore, further analysis was most feasible with these two options.

Table 1: Dependent and independent variables used for data analysis

Variables	Type/Label	Mean	Median
Dependent Variables			
Nr. of adaptation strategies	continuous/ 1 – 6	3	-
Agroforestry	dichotomous/no, yes	.45	0
Climate resistant cultivars	dichotomous/no,yes	.42	0
Independent Variables			
Institutional variables			
Access to credit	dichotomous/no, yes	.26	0
Cooperative member	dichotomous/no, yes	.52	1
Socio-demographic variables			
Age	continuous/years	45.41	-
Gender	dichotomous/male,fem.	-	1
Education	continuous/years	9.55	-
Farming experience	continuous/years	18.86	-
Farm characteristics			
Farm elevation	continuous/meters	1553	-
Farm size	continuous/hectare	1.17	-
Information access variables			
Attendance in training	ordinal/never-frequently	-	4
Information source: Internet	ordinal/never-frequently	-	2
Information source: Other farmers	ordinal/never-frequently	-	4

Note: ordinal variables have a scale from 0=never – 4=frequently; dichotomous variables: 0=no,1=yes; 0=female, 1=male

3.4.2 Multiple Regression

A multiple regression (MR) model was used to identify potentially significant predictors of the number of adaptation strategies used among the respondents (Greene 2003; Cramer 2003). The basic equation for an MR can be formulated in the following way:

$$\boldsymbol{y = x1\beta1 + x2\beta2 + \cdots + xK\beta K + \varepsilon} \qquad \textbf{(1)}$$

y represents the number of adaptation strategies (min.=1, max.=6) as a dependent variable where each x represents an independent variable noted in table 1. Each β is the coefficient of an independent variable and ε is the error term. The applied model was checked for multicollinearity by looking at the tolerance value as well as the variance inflation factor (VIF). We also checked the cook´s distance to understand the predictive capabilities of the model.

3.3.3 Binary Logit Regression

The Binary Logit Model (BLM) is a feasible analysis method when the outcome of the dependent variable is of a binary nature (Hosmer & Lemeshow 2000; Greene 2003; Cramer 2003). The dependent variables agroforestry and less climate-sensitive cultivars can take only two outcomes (using= yes or not using= no). These options were coded with the value 0 (=no) or 1 (=yes). The BLM reveals which of these factors affect the outcome of the dependent variable. An important condition of the BLM is no multicollinearity among the independent variables (Cramer 2003). All independent variables have been checked by the variance inflation factor (VIF), staying within 1.5 and 3.2. Based on this outcome, no multicollinearity between the independent variables can be assumed. The basic binary logit equation can be described in the following way:

$$\boldsymbol{log\left(\frac{p}{1-p}\right) = \beta_0 + \beta x} \qquad \textbf{(2)}$$

The dependent variable y can have the outcome of 1 or 0 based on the logarithm (*log*) of probability p. Based on the selected variables, we developed two models with two selected adaptation strategies and whether they have been used. β_0 represents the intercept while *X* is the vector of all independent variables included in the model based on table 1. The coefficients of the independent variables are expressed through *β*. In addition to the intercept, coefficient, and variable vectors in the original equation, *e* symbolizes the natural logarithm used for calculation. The probability of y=1 with a given value of the vector *X* of all independent variables can be calculated in the following way:

$$\boldsymbol{p(y = 1) = \frac{e\beta_0+\beta x}{1+e\beta_0+\beta x}} \qquad \textbf{(3)}$$

4. Results

4.1 Sample description

The sociodemographic characteristics of our sample varied from the average population of Nepal in terms of literacy, education, and family size (Table 2). The literacy rate of the respondents was 91.2%, which is considerably higher than the current literacy rate average for Nepal of around 64% (Index Mundi 2018). The average family size in this sample equaled 5.14 people. This is more than the national average value of 4.6 people per family (UNDP 2017). The youngest respondent was 25 years of age while the oldest 73 with an overall average of 45.41. Noteworthy is the average years of schooling, which equaled 9.55 years. This is higher than the average years of schooling in the whole of Nepal at around 3.3 years (UNDP 2017). A possible explanation for this deviation is that Ilam traditionally is one of the districts with the highest literacy rates in Nepal (Open Data Nepal 2019). The region is characterized by an above-average Human Development Index (HDI) among the districts of Nepal (Government of Nepal 2014). The East of Nepal (Province 1) has one of the highest shares of secondary education graduates in the country (NIRT 2016), is among the lowest in unemployment and poverty rates, as well as has an above-average number of schools per capita compared to other provinces of Nepal (Government of Nepal 2019). Karki et. al (2011) noted that many smallholder tea farmers in Ilam belong to ethnic groups that are considered a minority population with severe disadvantages. The most prevalent ethnic groups of Ilam district are Rai, Limbu, Gurung, and Tamang (Nepal Map, 2011). Table C contains further characteristics of the respondents.

Table 2: Sociodemographic characteristics of the respondents

Variable	Total (%)	Min.	Max.	Mean
Gender				
Male	75 (82.4%)	-	-	-
Female	16 (17.9%)	-	-	-
Literacy				
Literate	83 (91.2%)	-	-	-
Illiterate	8 (8.8%)	-	-	-
Marital status				
Single	2 (2.2%)	-	-	-
Married	87 (95.6%)	-	-	-
Divorced	0 (0.0%)	-	-	-
Widow	2 (2.2%)	-	-	-
Household members				
to 15 years	-	0	3	1.02
16-59 years	-	0	10	3.35
60+ years	-	0	3	0.77
Total average	-	-	-	5.14
Age (years)	-	25	73	45.41
Education (years)	-	0	15	9.55

4.2 Factors influencing climate change adaptation

4.2.1 Number of applied adaptation strategies

The average number of adaptation strategies used varied among the tea farmers (min.=1, max.=6) (Figure 2). The mean for all respondents in the application of adaptation strategies was 3.00.

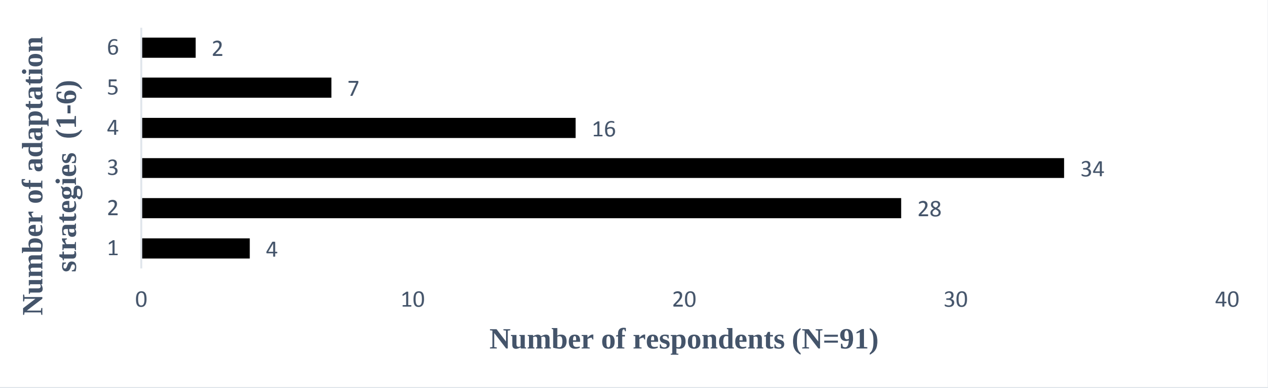

Figure 2: Number of adaptation strategies applied by respondents

The multiple regression shows that membership in a cooperative and attendance in training had a positive effect on the number of adaptation strategies applied (Table 3). In particular, cooperative membership of the respondents appears to notably increase the likeliness to apply a broader range of adaptation strategies towards climate change adaptation.

Table 3: Factors influencing the number of adaptation strategies used (min.=1, max.=6)

Variable	Coefficient	Std. Error	p-value
Access to credit	0.111	0.248	0.274
Membership Cooperative	**0.431**	**0.244**	**0.000**
Age	0.158	0.013	0.258
Gender	0.016	0.309	0.885
Education	0.098	0.033	0.415
Faming experience	0.129	0.019	0.317
Farm Elevation	0.024	0.001	0.815
Farm size	0.058	0.089	0.568
Attendance trainings	**0.242**	**0.102**	**0.035**
Info.Source: Internet	0.007	0.100	0.949
Info.Source: Other farmers	0.084	0.165	0.431

4.2.2 Specific tea cultivars and agroforestry as climate change adaptation strategies

Figure 3 shows all included adaptation strategies and their rate of application among the sample. Agroforestry was used by 50 respondents (54.9%) and switching to less climate-sensitive cultivars by 38 respondents (41.8%). Both options thus had a relatively balanced share between farmers who did and did not use these strategies. Given the number of the overall sample size (N=91) and the frequencies of usage for each adaptation strategy, further investigation was most feasible with agroforestry and switching to less climate-sensitive cultivars. We aimed to understand why some farmers are and others are not using these strategies. Further information on the most common tea cultivars was obtained from our main contact in the study area. The most widely used tea cultivars in Ilam district are clones from neighboring Darjeeling. These cultivars originate from China and have been selected to cope with the climate in this region. The cultivars are thus adjusted to the current climatic and topographic conditions of Ilam District (Mishra et al. 2014). Particularly the cultivar types “Tagda 78”, “Tagda 733”, “Gumtee”, “Fupxhiring Benen born”, “Tarapur”, “AV 2”, “AV 14”, and “Tista valley” are most prevalent among smallholder tea farms in Ilam. Some types are specifically drought resistant while others can cope better with uneven precipitation.

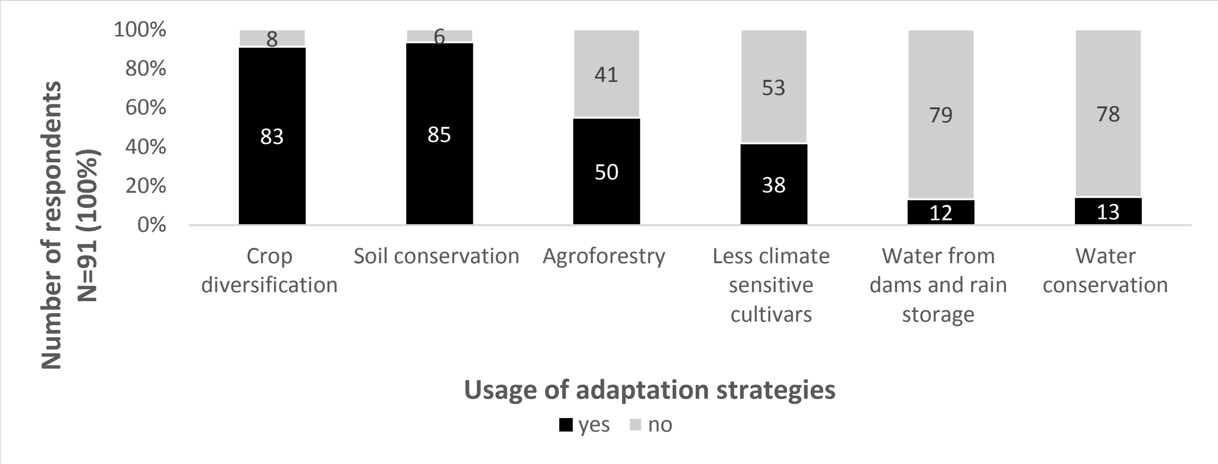

Figure 3: Application of specific adaptation strategies

Table 4 shows the results of the BLMs for the two selected adaptation strategies agroforestry and using less climate-sensitive cultivars. If all other factors remain unchanged, the odds ratio indicates a more than eight times higher probability to use agroforestry than if no credit was utilized. Members of a cooperative were almost six times as likely to make use of agroforestry and respondents who frequently use other tea farmers as information sources are over four times more likely to apply this strategy. Being a cooperative member positively influenced the usage of less climate-sensitive cultivars by almost five fold. Higher frequency in use of the internet as an information source leads to a higher probability of switching to less climate-sensitive cultivars by around 1.7 times per scale unit (0=never-4=frequently). Both independent variables were significant at a 5% level. Based on these results it becomes evident that institutional factors and information sources do influence the adaptation behavior of tea farmers.

Model 1 is significant at the 1% level and has an accuracy predicting 78% of the values correctly compared to the observed values, whereas Model 2 is significant at the 5% level and has an accuracy of predicting 70.3% correctly. According to Greene (2003), these results allow the assumption that the values based on the models including the predictors are different from the observed values.

The VIF among the significant predictors was 1.372, which is lower than the commonly accepted limit of 10. The tolerance value of the model is at 0.777 and thus above the threshold of 0.100. It can, therefore, be assumed that the model is applicable and there is no multicollinearity among the independent variables. We also looked at the casewise diagnostics and identified one case with a residual of 3.099. Checking the cook´s distance of this case revealed no influence on the model in its predictive capabilities. The adjusted R^2 has a value of 0.297, meaning it explains around 30% of the variations. The model is statistically significant with a p-value of 0.000.

Table 4: Factors affecting the adoption of agroforestry and less climate-sensitive cultivars

	Agroforestry (1)			Less climate-sensitive cultivars (2)		
Variable	p-value	odds ratio	S.E.	p-value	odds ratio	S.E.
Access to credit	**0.008**	**8.104**	**0.783**	0.430	6.710	0.646
Membership cooperative	**0.012**	**5.804**	**0.700**	**0.012**	**4.923**	**0.632**
Age	0.830	0.992	0.039	0.158	1.050	0.034
Gender	0.237	3.602	1.085	0.620	0.681	0.775
Education	0.226	0.877	0.108	0.194	1.117	0.085
Farming experience	0.587	0.970	0.057	0.276	0.949	0.048
Farm size	0.492	0.980	0.279	0.797	0.946	0.217
Farm elevation	0.491	1.001	0.002	0.446	1.001	0.002
Attendance in trainings	0.197	0.959	0.321	**0.041**	**1.705**	**0.272**
Inf.source: Internet	0.166	1.659	0.365	0.170	0.638	0.328
Inf.source: Other farmers	**0.027**	**4.128**	**0.642**	0.194	0.590	0.406

5. Discussion

Our study offers novel insights into the degree of climate change adaptation of smallholder tea farmers in Nepal through the fulfillment of all research objectives posed in the introduction. Outcomes of this study show that Nepalese tea farmers have a high awareness of climate change and try to adapt to it accordingly. While strategies such as crop diversification and soil conservation were applied by most of the farmers, other coping options such as irrigation, agroforestry, and the usage of less climate-resilient cultivars were only used partially. Despite a high degree of climate change awareness, adaptation has not reached its potential. The analysis of our data showed that farmers with credit access, frequent training participation, and a cooperative membership tend to better adapt to climate change than those who do not fall in those categories. The high degree of awareness of climate change goes in line with the mean of previous findings among farmers in various countries such as Italy (Menapace et al. 2015), South Africa (Findlater et al. 2018), Sri Lanka (Menike & Arachchi 2016), China (Shi-yan et al. 2018), and India (Sahu & Mishra 2013). The most common adaptation strategies among tea farmers found by Ashardiono and Cassim (2014) in Japan or Biggs et al. (2018a) in India were applied by the Nepalese farmers as well. However, it appears that these strategies are not always applied with a direct link to CSA. A possible explanation for the deviance between awareness and adaptation is the lack of including climate change threats into the farmers' mental models of everyday risks (Findlater et al. 2018). Previous studies suggest that smallholder tea farmers do not use the whole farm solely for tea production (Biggs et al. 2018b). In our case, the share of farm size dedicated to tea was on average 75.4%, which indicated that farmland was also devoted to other crops. Despite a high perceived impact of droughts on the tea farms, the adoption of strategies related to irrigation was low among the sample. This can be explained by a lack of irrigation infrastructure or missing knowledge about this topic. Less climate-sensitive cultivars were used by less than half of the respondents. Perennial crops (such as tea) are especially challenging when it comes to appropriate adaptation due to their long lifecycles (Lobell et al. 2006). According to the farmers, the usage of more climate-resilient tea cultivars can only be introduced gradually, as it takes several years for a tea plant to reach maturity. Adapting by protecting the tea from wind and sun exposure through agroforestry is, next to other factors, also dependent on the specific location of the tea farm. Socio-demographic factors and farm size did not play a statistically relevant role in the adaptation behavior of smallholder tea farmers in Nepal. Menike and Arachchi (2016), Trinh et al. (2018), and Ali and Erenstein (2017) noted a higher level of education and gender (being male) leads to an improved adaptation behavior. Previous studies argued about the impact of these factors (Sahu and Mishra 2013; Bedeke et al. 2018; Deressa et al. 2009). It is however important to consider that the targeted sample were smallholder farmers. The size of most farms ranged between 0.5 and 1.5 hectares. A small variance in farm size could be a possible explanation for the insignificant effect size of this factor.

We highlighted that farmer-to-farmer interaction and the internet were the most prevalent sources of accessing information about tea cultivation. Menike and Arachchi (2016) confirmed the importance of these channels. This relationship was also identified among tea farmers in Sri Lanka (Gunathilaka et al. 2018). The lack of using other sources of information would allow policymakers to diversify information access to the farmers. The IPCC Special Report on Climate Change and Land noted that the traditional knowledge of farmers has to be taken into consideration within the context of effective policy development (Mbow et al. 2019). That is why farmer-to-farmer exchange and training participation remains an important channel in which indigenous knowledge about agricultural practices is transferred. If farmers in our sample attended training more frequently, they were more likely to apply more adaptation strategies and had a higher probability of using climate-resilient cultivars. Only a small share of the respondents never participated in any training, while 66% participated in training once per year. 38.5% of the farmers even participated in training several times per year. Khanal et al. (2018) uncovered similar outcomes based on a study among Nepalese rice farmers, while Nguyen and Mitsumasu 2016) confirmed this among Vietnamese tea farmers. A lack of access to training is one of the main constraints for adapting to climate change (Deressa et al. 2009). This offers evidence of how important training and extension service provision is in the context of climate change adaptation. Nevertheless, the FAO (2010) pointed out the weaknesses of agricultural extension services in Nepal. Inappropriate technical expertise, weak motivation, and poor commercialization are hindering the effectiveness of training provided to the domestic farming sector. Farmers should hence not only be encouraged to attend training, but the quality of extension should be improved overall with a focus on educating farmers on climate change. Almost two-thirds of the farmers never heard about the strategic plans embedded in the National Tea Export Strategy 2017-2021 (ITC 2017) and only a minority of the sample was aware of its content. This outcome indicates a lack of dialogue between stakeholders of Nepal´s tea industry.

The most prevalent types of information for the farmers were knowledge about farming techniques and the market situation (e.g. tea prices, competitors). Since the awareness rate of the export strategy (ITC 2017) is low, a lack of communication among the individual stakeholders in the regional tea industry can be suspected. Agricultural research on climate change adaptation behavior concluded that credit access is one of the main drivers (Sahu & Mishra 2013; Trinh et al. 2018; Khanal et al. 2018; Fahad & Wang 2018). The Nepal Rastra Bank (2014) supports this assumption by analyzing the effect of microcredit on the Nepalese agricultural sector. Improved credit access has a positive effect on agricultural efficiency. Nepalese credit institutions are, however, reluctant to give credits, particularly to smallholder farmers. The conditions for granting loans can often not be fulfilled, and the high-interest rates make it less appealing for farmers to apply for credit. Therefore, most of the respondents (73.6%) did not have credit access in the past five years, while simultaneously farmers emphasized the importance of financial liquidity.

Our sample size (N=91) was smaller than anticipated, which is why the applicability to the overall research population is limited. Due to the lack of address lists of farmers, we could not collect our data based on random sampling. Being mostly dependent on an interpreter, only minor depth of discussions and explanations was possible. The research area was difficult to access. Some tea farms could only be reached by 4WD vehicles which took a substantial amount of time. This made the collection of field data a time-intensive and logistical challenge.

6. Conclusion and recommendations

While the government of Nepal intends to significantly increase tea exports, most farmers are not aware of these strategic plans. The obvious lack of communication is a barrier for the Nepalese tea sector to thrive in its full potential (Vij et al. 2018). Despite many tea farmers frequently attending training, the quality of these extension services remains questionable (FAO 2010). A lack of governmental support was perceived as one of the main barriers to appropriate adaptation from the farmers' point of view. The necessity to focus on more efficient policy implementation and interaction between policymakers and tea farmers becomes evident (Ensor et al. 2019). Connected to that are the difficulties for farmers to access credit due to high barriers set by involved financial institutions.

Although Nepal dramatically increased its spending on climate change mitigation (Nepali Sansar 2017), outcomes indicate a need for further investments and improved communication with tea farmers. As Nepal is prone to be hit by climate-induced disasters, it is not only the tea export strategy at stake. The economic dependency on agriculture could result in problems with domestic food security. We therefore recommend the Nepalese government to specifically educate tea farmers about the plans embedded in the national tea export strategy (ITC 2017). Without close cooperation with the producers, it could be difficult to achieve the target of increasing tea exports. Strengthening the tea sector could be carried out by preparing specific training and educating cooperative representatives helping to transfer the knowledge. In particular, cooperative memberships and farmer-to-farmer interaction should be encouraged. Cooperative members tend to use a greater variety of climate change adaptation strategies and have a better awareness of the benefits of CSA. Furthermore, access to quality training should be facilitated and topic related information should be provided on a continuous basis. The restrictions and barriers for credit access should be reduced, as farmers who had access to credit were more likely to better adapt to climate change. As adaptation strategies related to irrigation were not applied frequently, even though increased droughts were perceived as a major climate change effect, special attention should be given to educating farmers regarding the irrigation of tea plantations.

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Appendices

Appendix A

A: Questionnaire used for data collection

1.Did you hear about the term "Climate change" (CC) before?	
Yes	No

2.If yes, how often do you hear about this topic?		
Rarely	Sometimes	Frequently

3. Considering the following changes in weather, what is the perceived impact on your economic performance as tea farmer?	
	No impact at all – 0 1 2 3 4 – Very high impact
High amount of rainfall in a short period	0 1 2 3 4
Higher variation and unpredictability of rainfall patterns	0 1 2 3 4
Increase in temperature average	0 1 2 3 4
Increased drought periods	0 1 2 3 4
More annual rainfall	0 1 2 3 4
Unevenly spread rains	0 1 2 3 4

4.Please indicate to which extend you agree:					
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
CC in Nepal is an ongoing problem					
Tea plantations can decrease biodiversity through loss of plants and animals					
Extreme weather destroys my livelihood					
Droughts will occur more frequently					
Usage of banned or severely restricted chemicals is high in Nepal					
Tea production causes soil erosion					
Chemicals, such as pesticides and fertilizers pollute water					

5.Which of these climate change adaptation strategies do you already make use of?		
Crop diversification (e.g. different cultivars)	Yes	No
Soil conservation	Yes	No
Shade management	Yes	No
Switch to less climate sensitive cultivars	Yes	No
Making use of water from rain storage, pumps or dams	Yes	No
Water conservation and storage through rain water harvesting using ponds	Yes	No
Other:	Yes	No

6.Which constraints do make it particularly difficult for you as tea farmer to appropriately adopt to CC?	
	Not relevant-0 1 2 3 4-Very relevant
Lack of financial capital	0 1 2 3 4
Not enough information	0 1 2 3 4
Insufficient governmental support	0 1 2 3 4

7.Did you make use of a credit or loan to support your farm within the past 5 years?	
yes	no

8.How often do you make use of the following information channels regarding tea cultivation?	
	Never – 0 1 2 3 4 – Frequently
Internet	0 1 2 3 4
Television	0 1 2 3 4
Other tea farmers	0 1 2 3 4
Print media (e.g. newspaper)	0 1 2 3 4
Participation in trainings	0 1 2 3 4
Mobile phone	0 1 2 3 4
Other (please indicate):	0 1 2 3 4

9.Have you participated in trainings and workshops regarding tea farming?				
Very often (several times per year)	Frequently (around once per year)	Occasionally (around once every 2-3 years)	Seldomly (less than once in 5 years)	Never

10.Are you aware of the "National Tea Export Strategy 2017-2021" commissioned by the Nepalese government and the international trade centre?		
Never heard	Heard about it but do not know details	Aware about the content

11.How many tea farmer cooperative(s) are you currently a member of?
Number:
Please mention which cooperative(s):

12.Please indicate your gender:	
Male	Female

13.Please indicate your current age:

14.How long have you been working as a tea farmer? (years)

15.Would you consider yourself to be…?	
Able to write and read (literate)	Unable to write and read (illiterate)

16.Please indicate the number of years of your education:

17.What is your marital status?			
Single	Married	Divorced	Widow

18.How many people do live in your household?		
Children (-15 years):	Adults (16-59 years):	Elderly (60+ years):

19.Please indicate how many people are working on your farm and which gender they have:		
Total number:	Number of male workers:	Number of female workers:
Family members:	Male:	Female:
Paid workers:	Male:	Female:

20.Please indicate the size of your farm (in ha):

21. What is the share (in %) of your farmland size used for tea production only?

22.What is the elevation (altitude) of your tea plantation plots? (in meter)

23.Do you currently grow only tea or other crops (e.g. rice) too? If yes, please indicate which crops	
Yes	No
Other crops:	

Appendix B

Table B: Climate zones of Ilam district, Nepal

Climate zone	Elevation	Area Coverage (%)
Lower Tropical	below 300 meters	15.5%
Upper Tropical	300 to 1,000 meters	33.5%
Subtropical	1,000 to 2,000 meters	40.1%
Temperate	2,000 to 3,000 meters	10.6%
Subalpine	3,000 to 4,000 meters	0.3%

Note: composed of data from Lillesø et al. (2005)

Appendix C

Table C: Farm and institutional characteristics of the sample

Variable	Total (in %)	Min.	Max.	Mean
Farm features				
Size (Hectar)	-	0,2	10	1,2
Size (Ropani)	-	4	200	23,7
Share used for tea production (%)	-	30	95	75,4
Elevation (meter)	-	1100	1900	1554
Farm employees				
Total	-	2	34	7
Farming experience (years)	-	7	40	18,9
Usage of loan (credit)				
Yes	24 (26,4%)	-	-	-
No	67 (73,6%)	-	-	-
Cooperative member				
Yes	47 (51,6%)	-	-	-
No	44 (48,4%)	-	-	-
Training participation				
Never	5 (5.5%)	-	-	-
Seldomly (<once every 5 years)	9 (9.9%)	-	-	-
Occasionally (once every 2-3 years)	17 (18.7%)	-	-	-
Frequently (around once per year)	25 (27.5%)	-	-	-
Very often (several times a year)	35 (38.5%)	-	-	-
Aware of climate change				
Yes	79 (86.8%)	-	-	-
No	12 (13.2%)	-	-	-

Appendix D

Figure D 1: Map of Nepal with the position of minor and major tea producing areas

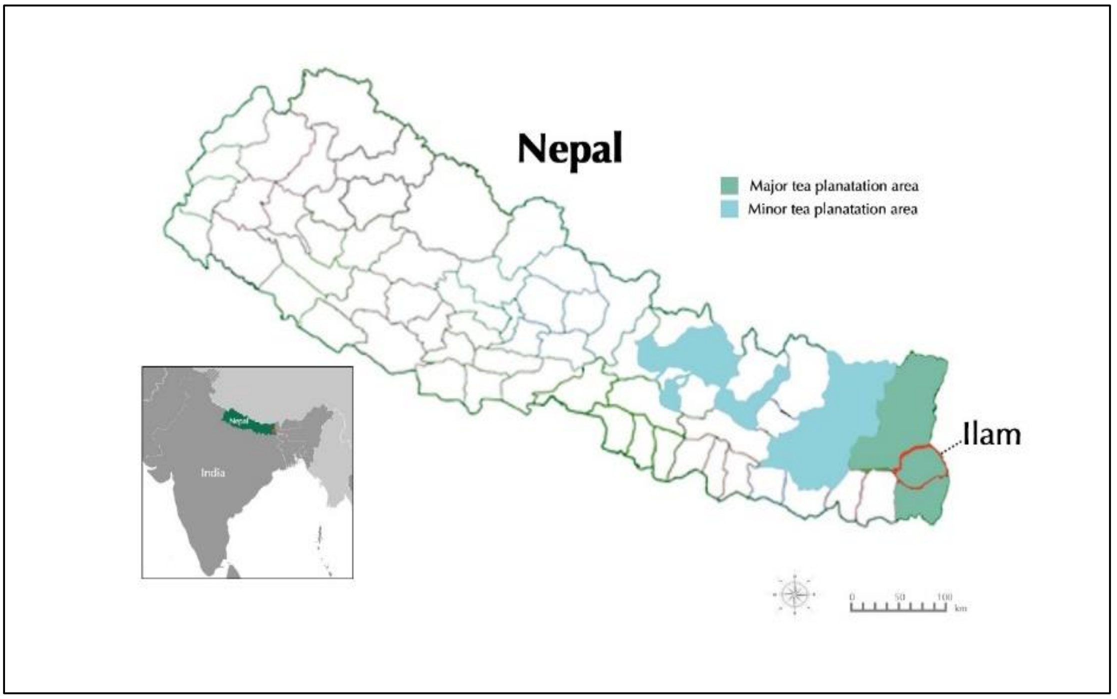
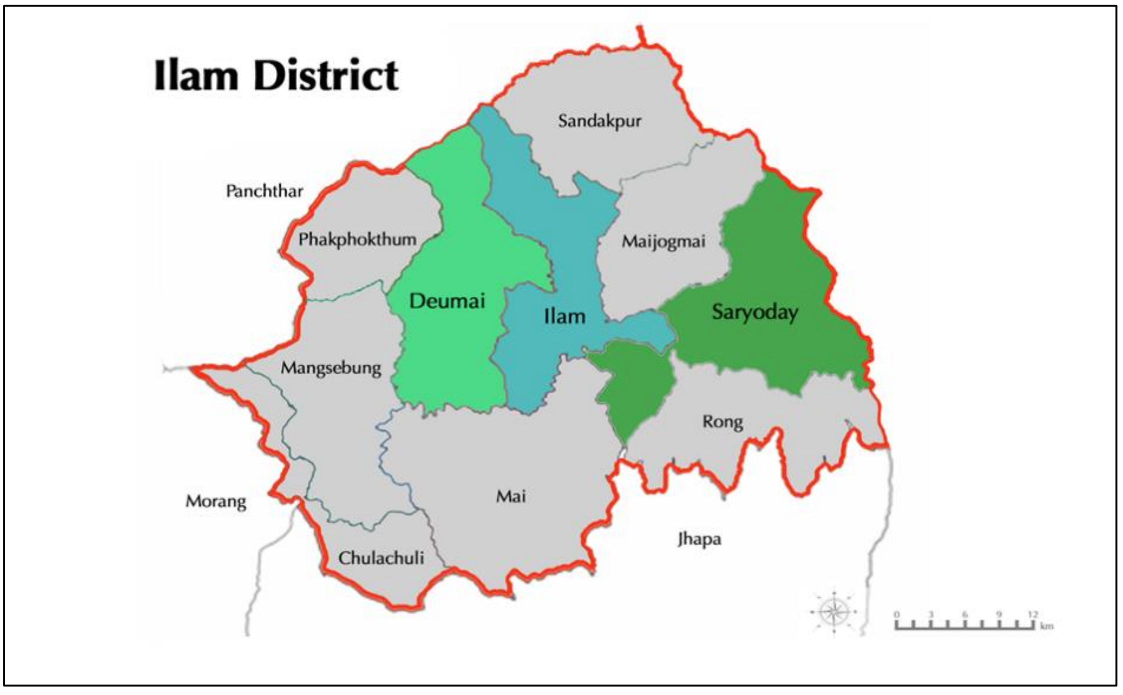


Figure D 2: Map of Ilam district with all municipalities



Conflict of interest statement

All authors have not any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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