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Study on the distribution of Francois's Langur (*Trachypithecus francoisi*) in NorthernVietnam under climate change scenario

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Abstract

Environmental niche modeling has been demonstrating to be a useful tool in conservation planning and be used widely in recent years. Therefore, many models have been developed for different purposes as well as different species so far. This paper presents an application of two of them (i.e. BIOCLIM and DOMAIN models) to study the distribution of Francoi's langur in Northeastern Vietnam. Surface climate data and distribution data from the previous surveys were used as model input. The model results represented potential distribution areas of *Trachypithecus francoisi* in current climatic condition and predictive areas in some future climatic conditions according to IPCC climate change scenario. The results also pointed out that the distribution of Francoi's langur might be moving to the North and the West under climate change influence. The authors also implemented a comparison whether BIOCLIM or DOMAIN model is more suitable for modeling the distribution of this specific species. This study is a continuing effort to apply environmental niche modeling for primate species. The results are meaningful in supporting scientists and managers to organize field study planning in order to conserve this species.

1. Introduction

In the recent years, predicting species distribution has become an important component of conservation planning, especially in climate change context; therefore a wide variety of modeling techniques have been developed. Environmental niche modeling (so called ecological niche modeling, niche modeling), which is defined as a process of using computer algorithms to generate predictive map of species' distribution in geographic space under current, past, and future climatic conditions, is being considered as a useful tool for this purpose. So far, niche modeling has being widely applied not only in conservation science, but also in studying invasive species, especially in biodiversity hot-pots (eg. Vietnam, China, India, South America, South Asia, etc.) (Vu Van Manh *et al*., 2010). However, because of the properties of models, the applications are limited for plants or lower animals such as insects, reptiles and amphibians, of which lives are totally depends on climate condition.

Francois's langur (other name: Francoi's leaf monkey, Tonkin leaf monkey or white side-burned black langur) with scientific name *Trachypithecus francoisi* is a leaf monkey. It belongs to Cercopithecidae family, Primates order and Mammals class.

Figure 1
Francois's langur
Trachypithecus francoisi
(Photo by Thach Mai Hoang)

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Francois's langur was first described by Poursargues (1898) in Southern Guangsix province, China. *Trachypithecus francoisi* is widely spreading, but the populations are highly fragmented and isolated. They live in limestone mountain area of monsoon semi-tropical forest, moist tropical and subtropical rainforest at elevation up to 1,500m where there are much of wood and climbing plant. The historical distribution of *Trachypithecus francoisi* in Vietnam may include the provinces Ha Giang, Cao Bang, Lang Son, Bac Kan, Thai Nguyen, Tuyen Quang and the Eastern part of two Northwestern provinces Lao Cai and Yen Bai. In worldwide extent, they distribute in Southern China (Tilo Nadler et al., 2002). This species is classified as Endangered (EN) on the IUCN Red List and listed on Appendix II of CITES. (IUCN, 2009; CITES, 2006).

2. Materials and methods

2.1. Collecting data method

a. Based map data

Based map data is spatial database of administrative areas in the research areas, including commune, district and province levels. The database is in SHP format, and freely downloaded from http://www.gadm.org.

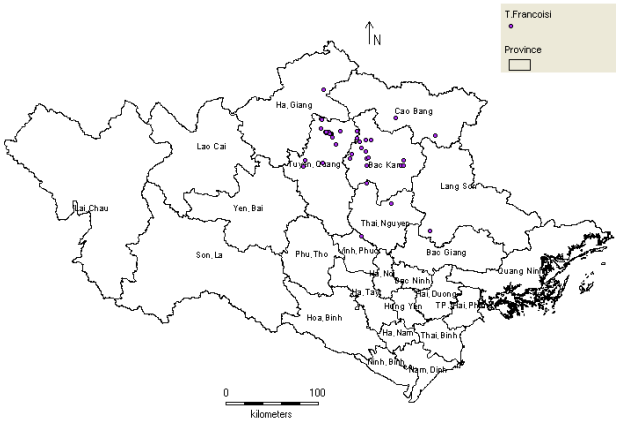

Figure 2
Specimen data of *Trachypithecus francoisi* in Vietnam

b. Climate data

The study used global climate layers (climate grids) with a spatial resolution of approximately 1 square kilometer. The data includes:

- Current condition data (interpolation of observed data, representative of 1950-2000) with 30arc-seconds resolution.
- Future condition data viz. 2020, 2050, and 2080, are calculated from climate model GCM (Global Climate Model) of CCCMA, according to climate change scenario A2 are from the 3rd report of IPCC (TAR). Spatial resolution is 30arc-second.

The data is freely downloaded in raster format (.BIL) from www.worldclim.org, then be processed in ArcGIS Desktop and DIVA-GIS.

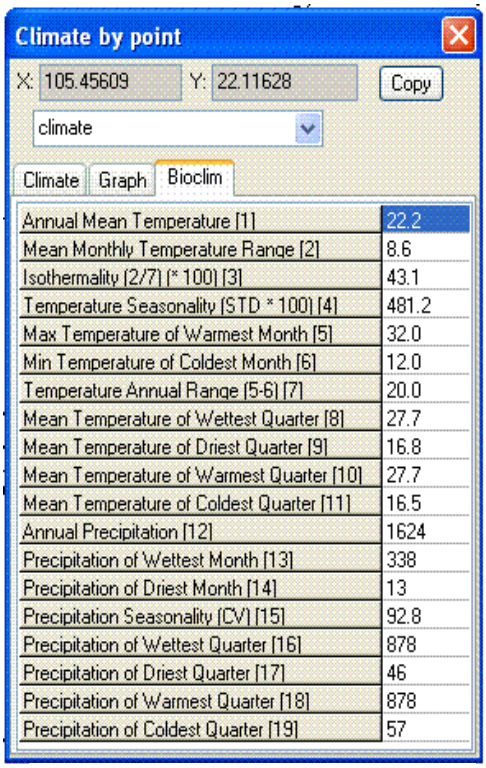

Figure 3
19 bioclimatic variables in 1 point

c. Species distribution data

Distribution data of *Trachypithecus francoisi* is collected from many different previous studies. The data includes 61 records, be digitized and mapped. The location of the recorded specimens is presented in Figure 2.

2.2. Modeling and mapping method

DIVA-GIS is a computer program for mapping and analyzing spatial data. It is especially useful for analyzing the distribution of creatures to generate geographic and ecological patterns. The analysis feature includes mapping of richness and diversity (even relying on molecular marker DNA data), mapping the distribution of specific feature, determination of areas with complementary diversity, and analysis of spatial autocorrelation. (Robert J. Hijmans et al, 2005).

Data from global climate model which includes average minimum temperature, average maximum temperature and average precipitation of study area, were used in model. The data were provided in raster format. Then, 19 bioclimatic variables is calculated (as in Figure 3) based on these data. Potential distribution areas are calculated by the similarity in value of these 19 bioclimatic variables between the cells which specimens occupied and other cells in the whole study area. New raster files will contain the value representing such similar levels.

In BIOCLIM model, four types of areas are generated according to the percentile envelope they occurred. Areas completely outside percentile range for one or more variables are assigned "0". The ones which fall within the 5-95 percentile are assigned "3", those outside this range but within the 2.5-97.5 percentile are assigned "2", and the ones outside this but within the 0 -100 percentile for all climate variables is "1".

On the other hand, DOMAIN model calculates the Gower distance statistic between each cell on the map and each cell that occupied by specimens, in term of the bioclimatic variable values. Consider cell A (with specimen) and cell B (on the map), the distance for a single climate variable is calculated as the absolute difference in the values of that variable divided by the range of the variable across all points. The Gower distance is then the mean over all climate variables.

$$d_{AB} = \frac{1}{p}\sum_{k=1}^{p}\frac{|A_k - B_k|}{range(k)}$$

The Domain similarity statistic is calculated as: $D = 1 - d_{AB}$

The maximum similarity between a grid cell and all points is mapped. A good match is thus a high number (R. J. Hijmans et al., 2005).

2.3. Model evaluation

To evaluate the accuracy of these models, the study used ROC/Kappa tool, which is available in DIVA-GIS. Parameters were used to evaluate prediction ability of model: AUC (Area Under Curve) and max-Kappa. The area under the ROC (Receiver Operating Characteristics) curve is used to evaluate species distribution modeling. A ROC curve is created by graph, the true - positive fraction against the false - positive fraction for all test points across all possible probability thresholds. The curve goes from (0, 0) to (1,1). Generally, the accuracy of these models is calculated by the area under the curve (AUC). AUC ranges from 0 to 1, the highest predictive power of a model is reach when AUC is 1 (R. J. Hijmans et al., 2005). Some studies recommended predict space. Excellent: AUC>0.9; Good if 0.8<AUC<0.9; Acceptable: 0.7<AUC<0.8; Bad: 0.6<AUC<0.7; Invalid: 0.5<AUC<0.6. With max-Kappa: Excellent: K>0.75; Good: 0.4<K<0.75; Low: K<0.4.

3. Results

The models used 19 bioclimatic variables, calculated from 4 input elements: min temperature, max temperature, precipitation, altitude. The bioclimatic variables represent annual trends seasonality and extreme or limiting environmental elements.

Distribution areas of *Trachypithecus francoisi* are divided into 6 levels: Not suitable, Low, Medium, High, Very high, Excellent.

3.1 Result of BIOCLIM model

In current condition, the potential distribution areas of *Trachypithecus francoisi* are in Northeastern provinces: Bac Kan, Tuyen Quang, Thai Nguyen, Lang Son, Cao Bang, Vinh Phuc, Ha Giang. In addition, the distribution area approaches to Vietnam-China border, and Tuyen Quang-Yen Bai border. The total areas are 16.189km^2.

The Very High areas mainly cover Bac Kan, Tuyen Quang, a part of Thai Nguyen province and Ha Giang. The total area is 862km^2.

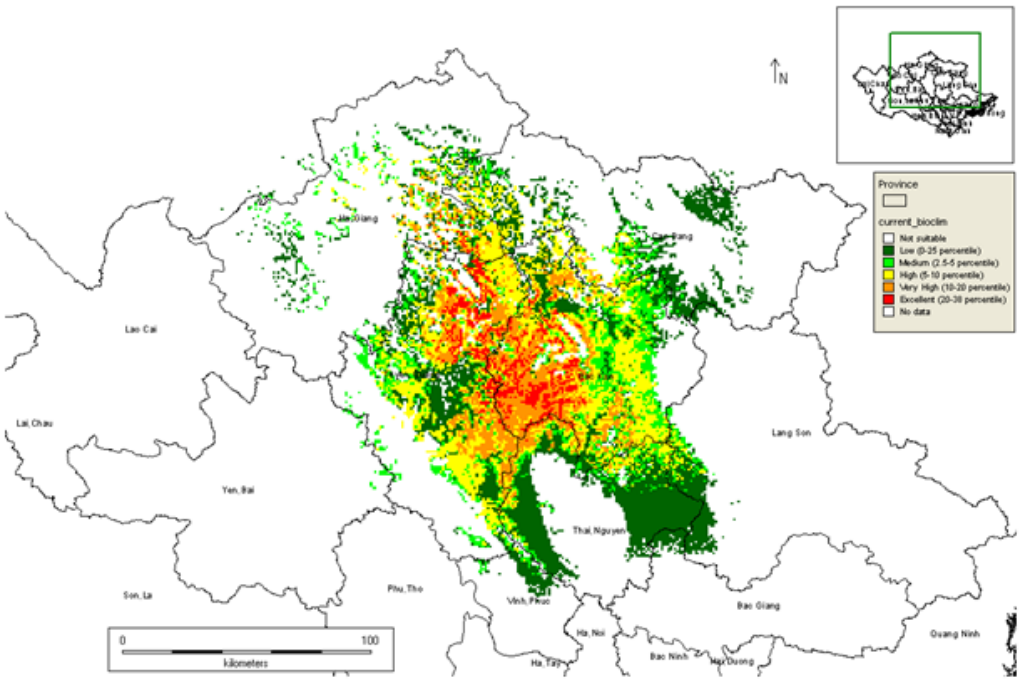

Figure 4
The potential distribution map of *T. francoisi* by BIOCLIM model under the current conditions.

In climate change condition, the temperature increases, the model shows two distribution trends: open widely and move to the North (Lao Cai and Yen Bai provinces).

In 2020, almost the distribution areas show a reducing trend to a lower grade. The total areas will be 17,661km^2; 10.7% larger than the current condition. According to Table 2, though the total potential distribution areas increases, only the Low area (36%) and the High area (24%) increases. Other areas show a decreasing trend; especially the Excellent area decreases the most (20.65%).

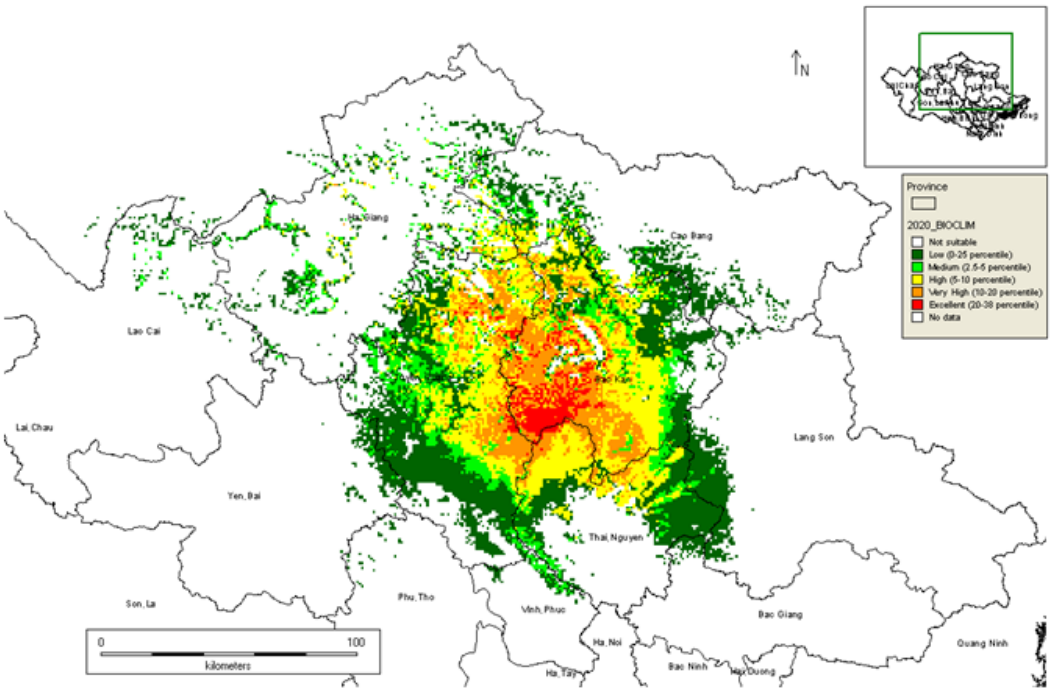

Figure 5
The potential distribution T. francoisi by BIOCLIM model by the year 2020

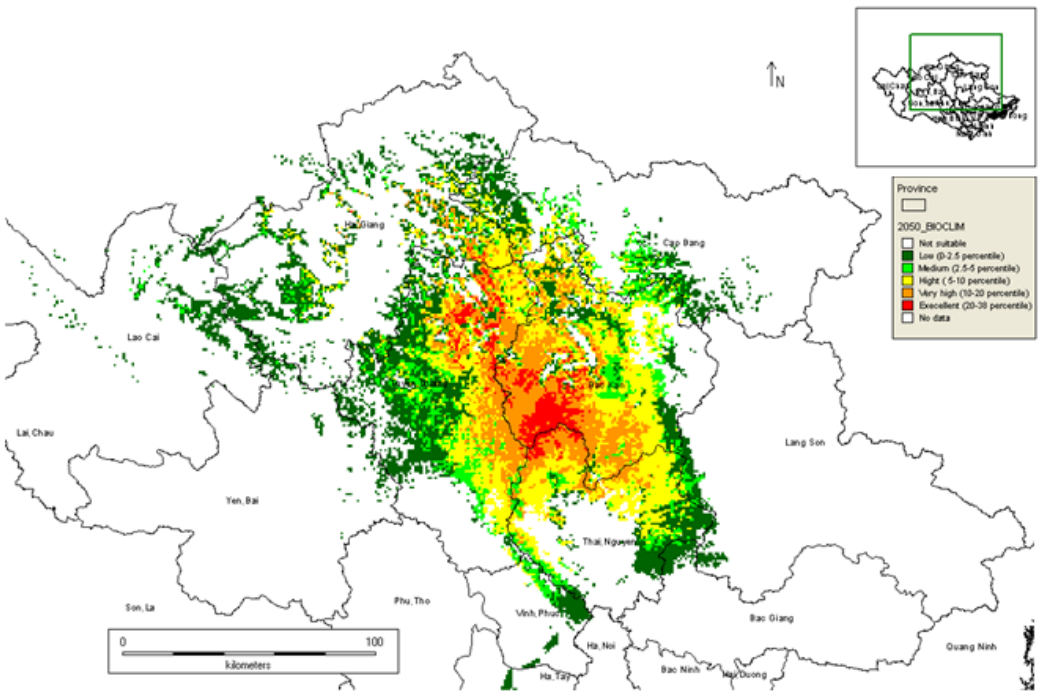

Figure 6
The potential distribution map of *T. francoisi* by BIOCLIM model by the year 2050

Result of predicting species distribution area is presented in the following table:

Table 1
Detail changes of potential distribution areas of *Trachypithecus francoisi*

Time	Area change	Level of distribution potential					
		Low	Medium	High	Very High	Excellent	Total
Current	Area (km^2)	5974	2502	4350	2501	862	**16.189**
	Change	0%	0%	0%	0%	0%	0%
2020	Area (km^2)	7518	2383	4631	2510	684	**17.661**
	Change	+25.85%	-4.76%	+6.46%	+0.36%	20.65%	+9.49%
2050	Area (km^2)	6893	2310	5060	3134	815	**18.212**
	Change	+15.38%	+7.67%	+16.32%	+25.31%	-5.45%	+12.9%

Base on the Table 1 the total areas are 18.212km^2, increase 12.9% in comparison with current climate condition. The Low, Medium, High and Very High areas increase (15.38%; 7.67%; 16.32%; 25.31%), but Excellent area decreases (5.45%). The Excellent area mainly covers Tuyen Quang (the North of Tuyen Quang province) and Bac Kan.To sum up, the BIOCLIM models showed that:

- Among distribution levels, the Low area is the largest, the Excellent is the smallest.
- The theoretical distribution areas tend to increase.
- All of the distribution areas tend to shift northward.
- In addition, most of the Very High and Excellent area degrades to lower levels.

3.2. Result of DOMAIN model

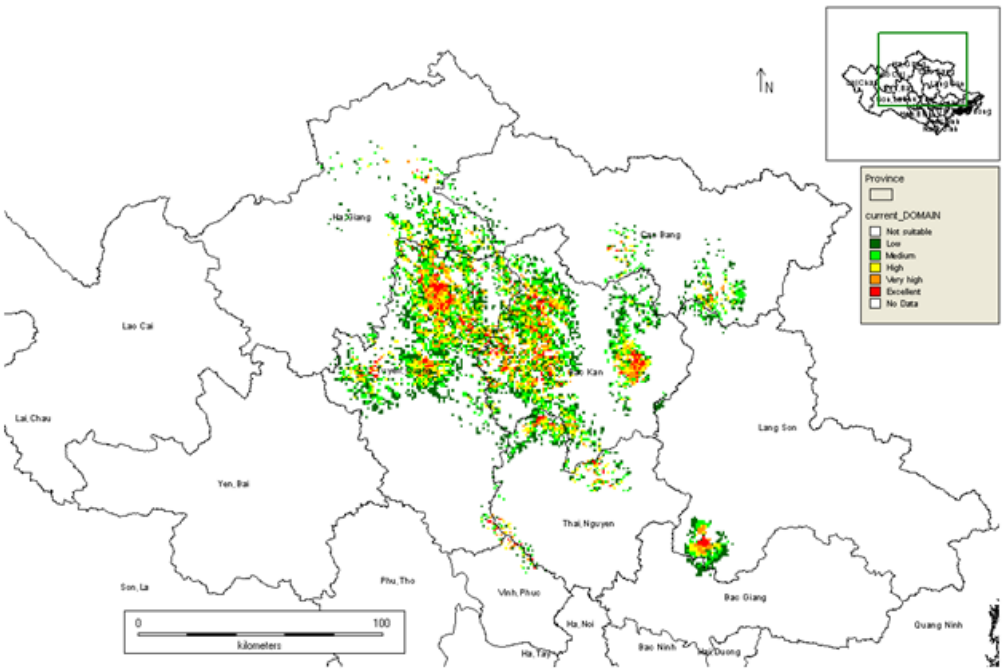

Figure 7
The potential distribution map of *T.francoisi* by DOMAIN model under the current condition.

In current condition, the potential distribution area of *Trachypithecus francoisi* in DOMAIN model is similar to BIOCLIM model, although the distribution is more dispersive than in BIOCLIM model. The total area is 5,912km^2, smaller than BIOCLIM model. The Excellent area is 293km^2, covers Tuyen Quang, Bac Kan, Thai Nguyen, Lang Son, Cao Bang, Ha Giang and Thai Nguyen - Vinh Phuc border (mainly in Tuyen Quang, Bac Kan, Lang Son).

In climate change condition, the result of DOMAIN model in 2020, 2050 also show a moving trend to the North, but the Very High and Excellent areas decrease. In 2020, the total areas increase 5% in comparison with current climate condition, the Low, Medium and High also increase, but Very High and Excellent decrease (1.31% and 11.26%). In 2050, the total areas are increase by 8.68% in comparison with current climate condition. The High and Excellent areas decrease by 1.31% and 4.78% respectively.

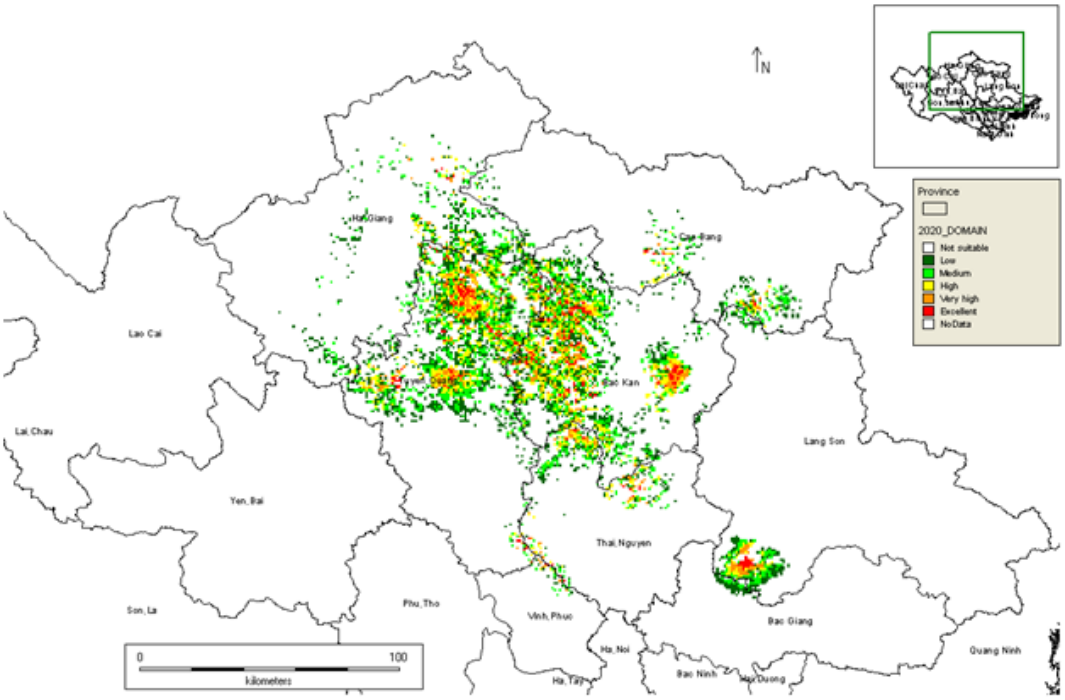

Figure 8
The potential distribution map of *T.francoisi* by DOMAIN model by the year the 2020

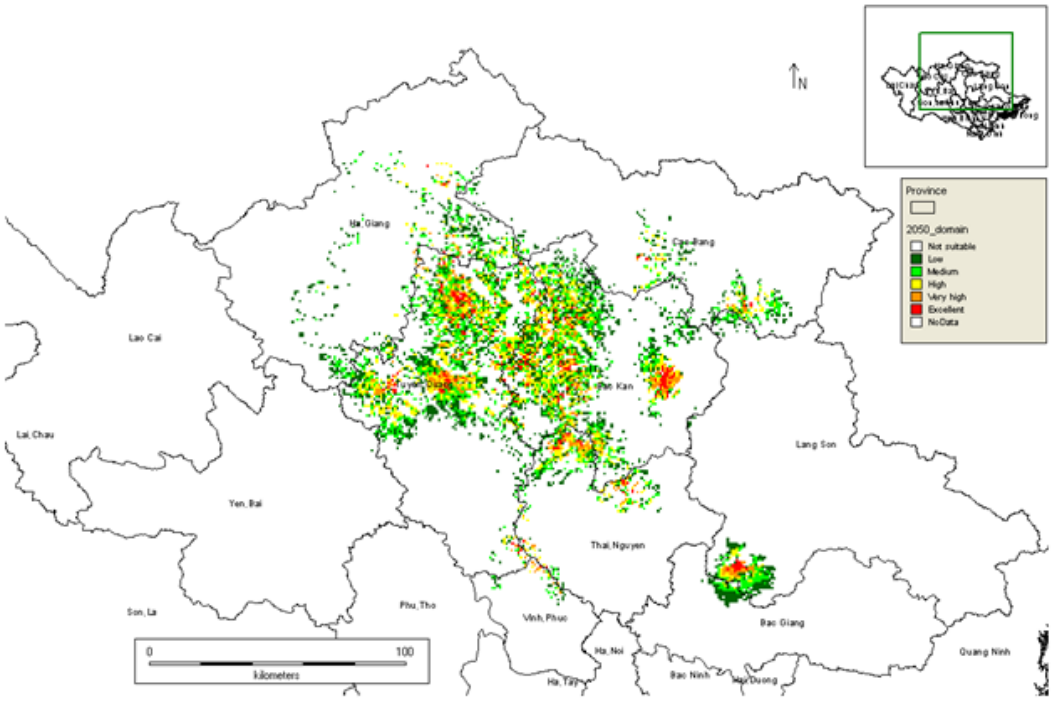

Figure 9
The potential distribution map of *T. francoisi* by DOMAIN model by the year 2080

Table 2
Detail changes of potential distribution areas of *Trachypithecus francoisi*

Time	Area change	Level of distribution potential					
		Low	Medium	High	Very High	Excellent	Total
Current	Area (km^2)	2,109	1,678	1,145	687	293	**5,912**
	Change	0%	0%	0%	0%	0%	0%
2020	Area (km^2)	2,293	1,799	1,178	678	260	**6,208**
	Change	+8.72%	+7.21%	+2.89%	-1.31%	-11.26%	+5%
2050	Area (km^2)	2,302	1,821	1,345	678	279	**6,425**
	Change	+9.2%	+8.52%	+17.47%	-1.31%	-4.78%	+8.68%

4. Discussion

4.1 The accuracy of the model

a. Quantitative evaluation

To evaluate accuracy of two models, the study used ROC/Kappa tool, which are in available DIVA-GIS software. The result is presented in the following tables:

Table 3
The AUC value of two models:

Model	Accuracy by ROC/Kappa		
	Current	2020	2050
BIOCLIM	0,99	0,982	0,944
DOMAIN	0,94	0,926	0,925

The AUC (area under the curve) ranged from 0.94 to 0.99 (mean 0.964) in BIOCLIM model, and model from 0.944 to 0.99 (mean 0.972) in DOMAIN. AUC of BIOCLIM model in current and climate change condition respectively higher than in DOMAIN model.

Table 4
The max-Kappa value of two models:

Model	Accuracy by AUC		
	Current	2020	2050
BIOCLIM	0,967	0,954	0,873
DOMAIN	0,876	0,853	0,85

In BIOCLIM model, the max-Kappa ranged from 0.873 to 0.967 (mean 0.93), in DOMAIN model from 0.85 to 0.876 (mean 0.86). The max-Kappa indexes of all levels in BIOCLIM are higher than in DOMAIN respectively and within very good range.

Base on result of AUC and max-Kappa, the BIOCLIM model is better than DOMAIN model.

b. The qualitative evaluation

First of all, the model results show that the distribution area of the *Trachypithecus francoisi* is located in Northeastern Vietnam. This is consistent with previous studies on this species.

Besides, the results of the model coincide with some specimens which are not included in the input data. For instance, according to the survey carried out by Thai Nguyen Department of Forest Ranger along with a researchers group of Vietnam Forestry University (VFU) have discovered 8 individuals in Than Sa - Phuong Hoang nature reserve (Vo Nhai district, Thai Nguyen province) in August 2011. However, most of specimens collected in the past are not entirely in the Excellent area in the model (mainly located in Very High area).

5. Conclusion and recommendation

According to BIOCLIM model, the potential distribution area of *Trachypithecus francoisi* in current condition is 16,189km^2 and mostly covers the Northeastern Vietnam. In climate change condition, the distribution areas showed a moving trend toward the North, the total area increased, however, very High and Excellent areas decreased. On the other hand, according to DOMAIN model, under current condition, the total area is only 5,912km. In climate change condition, DOMAIN results the same trend with BIOCLIM model. It is not only smaller but also more dispersed than BIOCLIM model.

The study used ROC/Kappa tool to evaluate accuracy of models. The result shows that the BIOCLIM model is better than DOMAIN model. Although the model is still limited e.g. not mentioned some essential factors such as vegetation cover, land use, bio-interaction and impact of human activities, this could be useful in researching species distribution and supporting the scientists and managers in terms of reservation planning, especially when Vietnam has several conservation areas, including Sinh Long - Lung Nhoi Species and Habitat Conservation Area (Tuyen Quang province) and Nam Xuan Lac Species and Habitat Conservation Areas (Bac Kan province).

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