International Journal of Ecology and Environmental Sciences 43 (2): 129-135, 2017
ISSN: 2320-5199 (Online)

Identifying Protected Areas Suitable for Conservation of *Cycas pectinata* Buch. Ham. in Southeast Asia Under Climate Change Scenario

ADITYA PRADHAN[1] AND ARUN CHETTRI[*]

Taxonomy and Biodiversity Laboratory, Department of Botany, Sikkim University, 6th mile, Tadong, Gangtok, 737102, Sikkim, India
[1] Email: apradhan512@gmail.com
[*]Author for correspondence: E mail: achettri01@cus.ac.in

ABSTRACT

Cycads are considered one of the most threatened groups of plants, with 62 % of all species listed on the IUCN Red List. Therefore in order to implement sustainable conservation strategy, it is imperative to understand the impacts of changing climate on both ecosystem and at species level. We therefore presented an assessment on current and future habitat suitability distribution of *Cycas pectinata* Buch.-Ham., using a maximum entropy (MaxEnt) species distribution model. The projected future distribution map was then overlaid onto protected areas of Southeast Asia for further analysis. Out of 1938 protected areas identified in the 10 southeast countries, only 190 protected areas would remain suitable by the end of 2050 under climate change scenario (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). The MaxEnt model performed better than random with an average test AUC value of 0.975 (±0.001). The AUC values thus confirm the accuracy of model prediction based on 73 occurrence points. A significant reduction in the suitable habitat was also observed under future climate change scenario, as a result of which the species may not be able to adapt to modification caused by climate change further leading to reduction in population size.

Key Words: Climate change, Cycads, ENM, MaxEnt, Protected area, Vulnerable

INTRODUCTION

According to IPCC Fourth Assessment Report, South East Asia is expected to be adversely affected by changing climate. Thus climate change is projected to have pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development in the region (IPCC 2007). Numerous studies have shown rapid increase in global climatic conditions in the last decade and thus have estimated similar trends for the coming years (Cordellier and Pfenninger 2009). The changes on the distribution patterns of the species and biodiversity as a whole are expected and are considered one of the major consequences of climate change (Botkin et al. 2007, Svenning et al. 2009). The Intergovernmental Panel on Climate Change therefore underpins the importance of conserving biodiversity in the face of changing climate conditions. Some of the major consequences of climate change include changes in distribution pattern of the species, increased rate of extinction, changes in phenology (Iverson and Prasad 2001, Thompson et al. 2009). In this regard, Species distribution modeling (SDMs) or Ecological niche modeling (ENM) has become an imperative tool for predicting the probable impact of climate change on floral distribution (Bakkenes et al. 2002, Chris et al. 2004, Thuiller et al. 2005). The model is developed by correlating species existence and its biophysical environment to predict the current as well as the future distribution of the species (Elith et al. 2006, Peterson 2006, Kumar and Stohlgren 2009). There are many modeling technique (MaxEnt GARP, and BIOCLIM) available for predicting the suitable habitat distribution of a species, but the input parameters and criteria differ. Most of the SDMs use both presence as well as absence data to model the

distribution of the species unlike MaxEnt which can run with presence data alone (Phillips et al. 2006).

Numerous studies have been conducted in regard to identification of priority areas for reintroduction and conservation of both floral and faunal element (Martı et al. 2006, Callmander et al. 2007, Mihoub et al. 2014, Upadhaya et al. 2016). However there are fewer examples of studies conducted in regards to identification of protected area under climate change scenario for conservation of threatened species (Beltramino et al. 2015). Therefore this study aims to (1) to model the distribution of *Cycas pectinata* both under present and future climate change scenario (2) to identify protected areas which would remain suitable under future climate change scenario and plan for conservation of species accordingly.

THE STUDY AREA

Southeast Asia is a sub-region of Asia, consisting of the countries that are South of China, East of India, West of New Guinea and North of Australia. It consists of two geographic regions: (1) Mainland Southeast Asia, also known as Indochina region which includes countries like Vietnam, Laos, Cambodia, Thailand, Myanmar (Burma) and West Malaysia and (2) Maritime Southeast Asia, which includes countries like Indonesia, East Malaysia, Singapore, Philippines, East Timor, Brunei, Cocos (Keeling) Islands, and Christmas Island. The present study primarily focuses on countries of Mainland Southeast Asia, where the species if found to be distributed.

Studied Species and Species Records

C. pectinata (Figure 1) one of the most wide spread cycad is under severe threat with its populations declining at a pace as compared to any other species of *Cycas*. The species is assigned to Vulnerable (VU) category by IUCN (Nguyen 2010), due to an estimated decline in natural habitat of more than 30% over the past 90 years (three generations/120 years). The species is also included in CITES Appendix III.

The present study was based on presence record for *C. pectinata* obtained from Global Biodiversity Information Facility (GBIF) (www.gbif.org) and scientific literature (Singh and Singh 2014, Khuraijam and Singh 2015). These records were then checked for spatial errors using Diva-GIS (Hijmans et al. 2001) The duplicate occurrence points were trimmed using ENM Tools 1.3 (Warren et al. 2010). Therefore out of 104 distributional records only 73 records were used in model calibration, evaluation and projection. All the presence records collected from secondary sources were derived from the website www.fallingrain.com, which was then saved to CSV format in order to use for modeling.

Figure 1. *Cycas pectinata* in its Natural habitat.

METHODOLOGY

Environmental Data

In order to develop the niche model, environmental variables for current and future conditions were obtained from Worldclim v. 1.4, having a spatial resolution of 30 arc seconds (~1 km^2) (Hijmans et al. 2005) (Table 1). Intergovernmental Panel on Climate Change (IPCC) data in its fifth Assessment Report (Moss et al. 2010) for four different climate change scenarios was used for future

prediction. These are Representative Concentration Pathway (RCP) scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). RCP 8.5 indicates an increase in greenhouse gas emissions throughout the 21st century leading to high greenhouse gas concentration. RCP 6.0 represents intermediate green house gas emission where total radiative forcing stabilizes after the year 2100 by use of technologies. RCP 4.5 represents a more positive scenario where emissions peak around 2040 and then reduces. RCP2.6 pathway assumes continuous net negative anthropogenic green house gas emissions after the year 2070.

Table 1. Percent contribution of the bioclimatic variables in the MaxEnt models for *C. pectinata*; values shown are averages over 20 replicate runs. Variables without any value (indicated by - symbol) were removed because of high multicollinearity. Source: www.worldclim.org

Environmental data	Unit	% contribution
Bio1 - Annual mean temperature	C	2
Bio2 - Mean diurnal temperature range [mean of monthly (max temp – min temp)]	C	1.1
Bio3 - Isothermality (Bio2/Bio7) (*100)		39.2
Bio4 - Temperature seasonality (SD × 100)		0.5
Bio5 - Maximum temperature of warmest month	C	2.7
Bio6 - Minimum temperature of coldest month	C	-
Bio7 - Temperature annual range (Bio5 – P6)	C	-
Bio8 - Mean temperature of wettest quarter	C	-
Bio9 - Mean temperature of driest quarter	C	-
Bio10 - Mean temperature of warmest quarter	C	-
Bio11 - Mean temperature of coldest quarter	C	-
Bio12 - Annual precipitation	mm	18.8
Bio13 - Precipitation of wettest month	mm	0.1
Bio14 - Precipitation of driest month	mm	10.3
Bio15 - Precipitation seasonality (CV)	mm	7
Bio16 - Precipitation of wettest quarter	mm	-
Bio17 - Precipitation of driest quarter	mm	-
Bio18 - Precipitation of warmest quarter	mm	16
Bio19 - Precipitation of coldest quarter	mm	2.4

Ecological Niche Modeling

MaxEnt or Maximum entropy modeling algorithm (version 3.3.3k) (Phillips et al. 2006) was used for mapping the potential geographic distribution of *Cycas pectinata* in Southeast Asia. We used MaxEnt model because it has high success rate with small sizes as compared to other modeling methods (Elith et al. 2006, Pearson et al. 2007; Kumar and Stohlgren 2009). The highly correlated pairs of environmental layer ($r > 0.9$) were first subjected to correlation test using ENM Tools 1.3 (Warren et al. 2010). The variables having correlation value of > 0.9 were discarded and thus out of 19 bioclimatic variable 11 variables were used for modeling (Supplementary material 1). We performed 20 replicates run with the set of variables and in order to compare the current and future potential distributions of the species, binary maps (suitable/unsuitable habitat) were derived using the 10 percentile training presence logistic threshold. The extent of suitable areas (current and future) was quantified and analyzed with Arc View GIS 3.3. Cross validation technique was employed where samples were divided into replicate folds and other parameters were set default as the program is calibrated on a wide range of datasets (Phillips and Dudik 2008). The average, maximum, minimum, median and standard deviation were also generated from the replicated run. The quality of the model was evaluated based on Area under Curve (AUC) value and was graded following Thuiller et al. (2005) as very good ($0.95 < AUC < 1.0$), good ($0.9 < AUC < 0.95$), fair ($0.8 < AUC < 0.9$) and poor ($AUC < 0.8$).

Protected Areas Analysis

In order to determine the habitat suitability of *C. pectinata*, the current and future distribution maps for the different scenarios were overlapped onto the protected areas of 10 Southeast Asian Countries. The network was downloaded from World Database of Protected Areas (UNEP-WCMC 2012); http://protectedplanet.net). The analysis was performed using Arc View GIS v.3.3.

RESULTS

The logistic output for current habitat suitability distribution of *C. pectinata* was with high success rate. AUC score for the training and test data were 0.975 (±0.001) and 0.968 (±0.034) respectively that indicate high level of accuracy in the model prediction. The potential distribution area for *C. pectinata* under current and future climate change scenario is shown in Figures 2 and 3. The 10 percentile training presence logistic

threshold used for binomial conversion was 0.184. At this threshold, the area predicted as suitable for the species was ~1,620,421 km^2 for the full geographical range (*n=10* countries) of the species which includes protected area (*n=1,938*) covering an area of ~252,613 km^2 predicted to be suitable. Under current climatic scenario most part of Southeast Asian country was found to be suitable (Figure 2). However projections of future distribution showed differences in habitat suitability under climate change scenario (Figure 3). Under climate change scenario (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) for the year 2050, the suitable habitat for *C. pectinata* was estimated to be about ~1,446,881 km^2, ~1,196,403 km^2, ~1,412,206 km^2 and ~1,286,536 km^2 respectively. Similarly the suitable habitat for *C. pectinata* in case of protected area analysis was estimated to be about ~ 226,612 km^2, ~199,649 km^2, ~220,723 km^2, and ~203,983 km^2 respectively (Figure 4).

Since the percentage of habitat suitability differs in different protected areas, we considered only those protected areas which have ≥90% habitat suitable under future climate change scenarios for the year 2050. Therefore out of the 1,938 protected areas identified in 10 Southeast Asian counties; only 190 protected area (Bangladesh=4, Bhutan=5, China=68, Cambodia=2, India=38, Lao=16, Myanmar=9, Nepal=2, Thailand=15, Vietnam=31) would remain suitable by the end of 2050 under future climate change scenario, RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 (Supplementary material 2).

DISCUSSION

Cycads are considered one of the most threatened groups of plants, with 62 % of all species listed on the IUCN Red List (Nagalingum et al. 2011). *C. pectinata* is one such species categorized as Vulnerable A2c ver. 3.1 by IUCN (Nguyen 2010) and with only 273 individuals surviving in the Northeastern states of India (Singh and Singh 2014) and 200,000-250,000 mature individuals surviving worldwide, the species is at present under severe threat with a decreasing trend of population (Nguyen 2010). Therefore identification of conservation sites for protection of the existing population is a need of an hour. The model predicted that the suitable habitat of *C. pectinata* will get reduced under predicted level of climate change, and thus such changes may further lead to decline in natural population. However as most cycads possess considerable phenotypic plasticity in response to the environment (Prathapan 2006) the species may adapt to changing climate as it has survived the great Permian extinction in the past. Amongst all the input environmental variables, Isothermality (Bio3) and Annual precipitation (Bio12) was the most influential variable which together contributed 58 % to the MaxEnt model (Table 1). The importance of relatively high precipitation for the survival of *C. pectinata* has also been reported by Bhuju and Joshi (2009).

Out of the 190 protected areas identified as suitable in 10 Southeast Asian countries, China has the highest

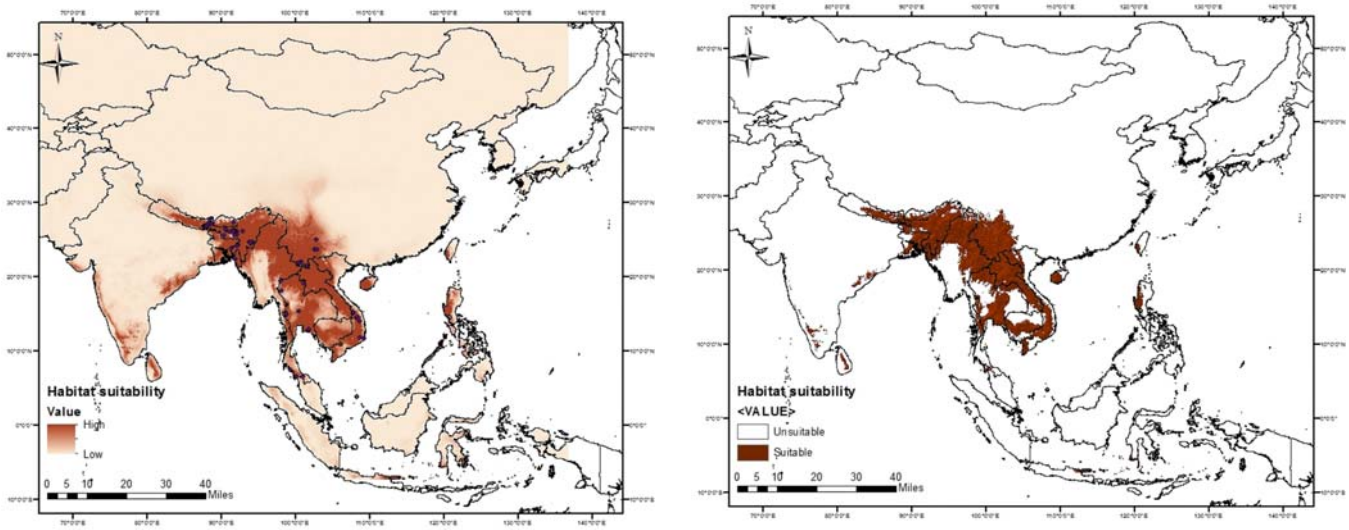

Figure 2. Predictive distribution mapping for *C. pectinata* (A -left) logistic format for current climate and (B- right) threshold format (*10 percentile training presence*) for current climate

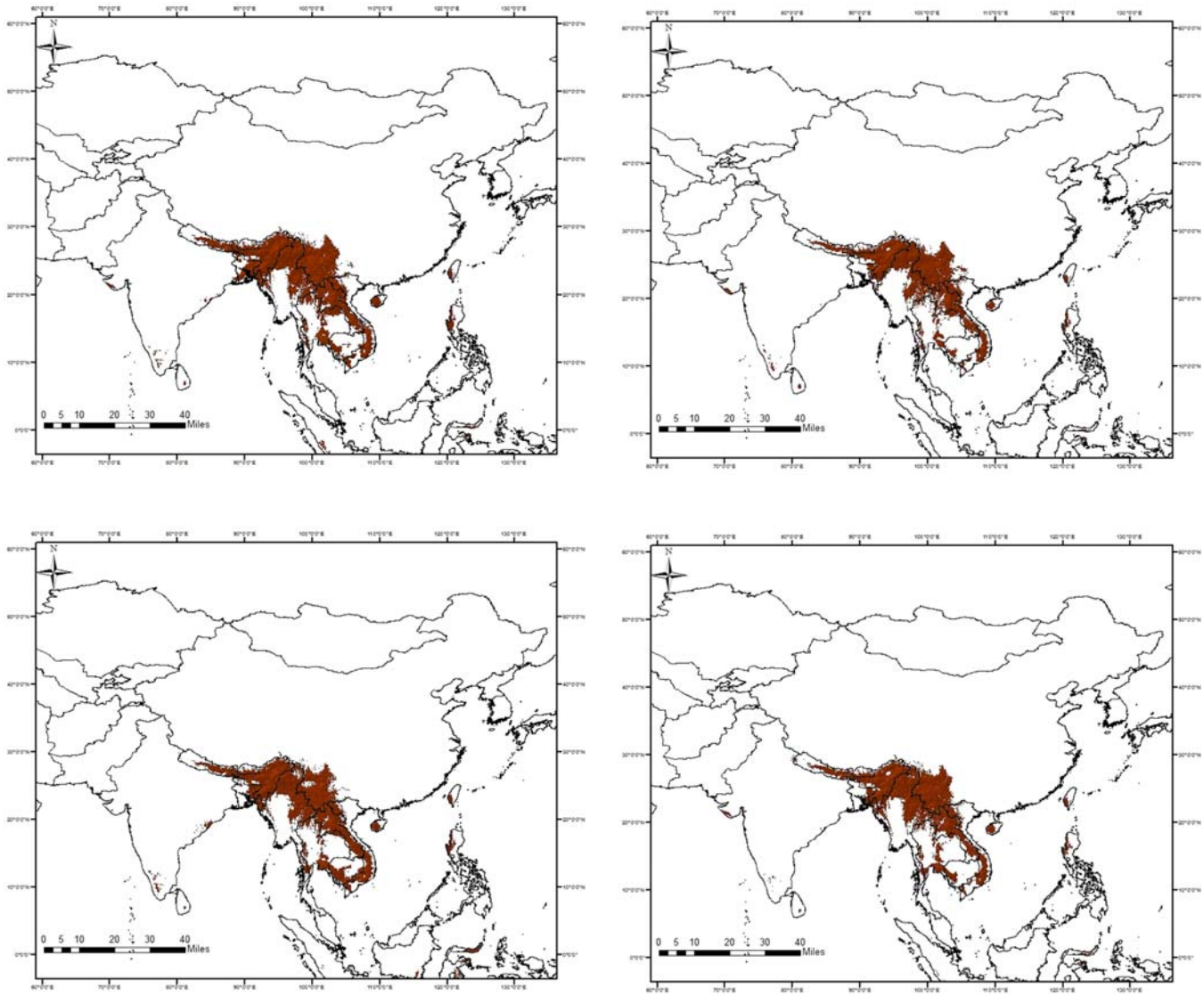

Figure 3. Predictive distribution mapping for *C. pectinata* under climate change scenario
Clockwise: (A) RCP_2.6; (B) RCP_4.5; (C) RCP_6.0 ; and (D) RCP_8.5

number of protected area (*n=68*) followed by India (*n=38*) and Vietnam (*n=31*). The use of ENM tools for conservation of Cycads has also been suggested by (Prathapan 2006). Therefore this study further highlights the importance of ENM in identifying protected area suitable for conservation of threatened species.

The extraction of male cone for food and medicine is one of the major factors causing threat to the species and with rapid transformation of natural habitat due to urbanization and human settlements, posing additional threat to the species, the only way out to protect the existing plant population is through insitu conservation in the protected areas identified through Ecological Niche Modeling.

ACKNOWLEDGEMENTS

We would like to extend our sincere thanks to the Head, Department of Botany, Sikkim University for providing necessary logistic facilities and Dr. Dibyendu Adhikari, Research Scientist, Department of Botany, North-Eastern Hill University, Shillong for his technical guidance in performing the model. AC designed and analyzed the results; AP designed, performed, analyzed the data and wrote the paper.

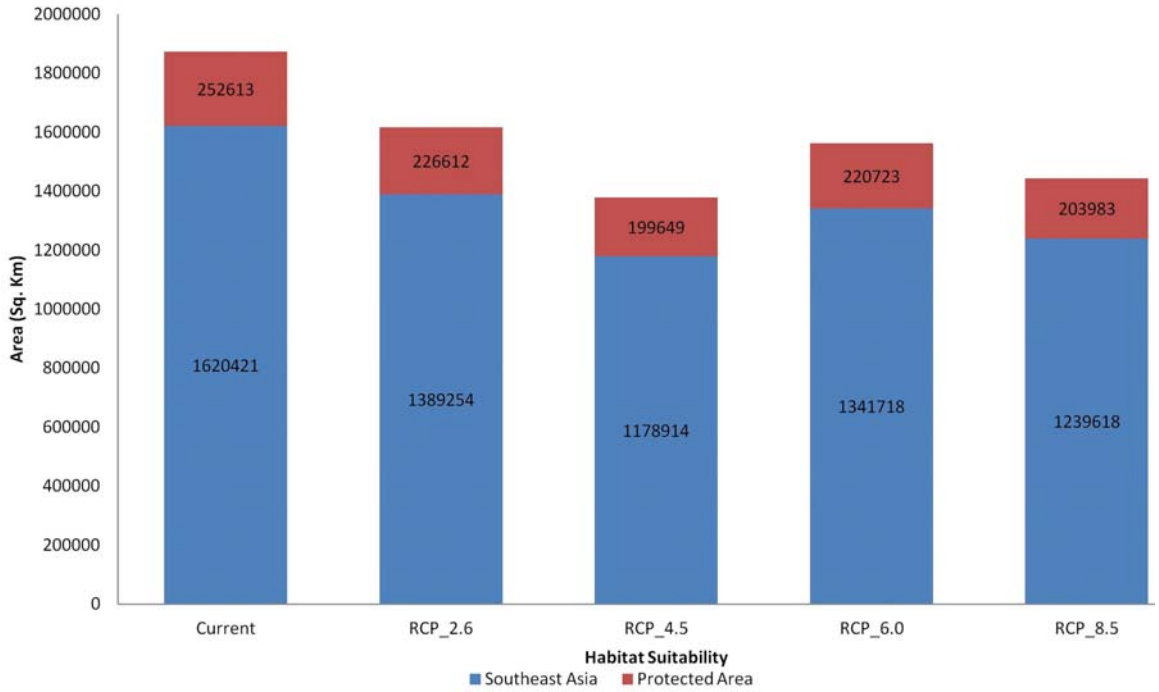

Figure 4. Habitat suitability for *C. pectinata* under current and future climate change scenario (*Note: Figure at the top of the bar represents areas*).

REFERENCES

Bakkenes, M.; Alkemade, J. R. M.; Ihle, F.; Leemans, R. and Latour, J. B. 2002. Assessing effects of forecasted climate change on the diversity and distribution of european higher plants for 2050. Global Change Biology 8: 390–407.

Beltramino, A. A.; Vogler, R. E.; Gregoric, D. E. G. and Rumi, A. 2015. Impact of climate change on the distribution of a giant land snail from south america : predicting future trends for setting conservation priorities on native malacofauna. Climatic Change 131: 621–633.

Bhuju, D.R. and Joshi, G.P. 2009. Records of *Cyathea spinulosa* Wallich ex Hooker (cyatheaceae) and *Cycas pectinata* Griff. (Cycadaceae) from the Churiya hills of eastern nepal. Nepal Journal of Science and Technology 10: 69–72.

Botkin, D.B.; Saxe, H.; Araujo, M.B.; Betts, R.; Bradshaw, R.H.W.; Cedhagen, T.; Chesson, P.; Dawson, T.P.; Etterson, J.R.; Faith, D.P.; Ferrier, S.; Guisan, A.; Hansen, A.S.; Hilbert, D.W.; Loehle, C.; Margules, C.; New, M.; Sobel, M.J. and Stockwell, D.R.B. 2007. Forecasting the effects of global warming on biodiversity. Bio Science 57: 227–236.

Callmander, M.W.; Schatz, G.E.; Ii, P.P.L.; Laivao, M.O.; Raharimampionona, J.; Andriambololonera, S.; Raminosoa, T. and Consiglio, T.K. 2007. Identification of priority areas for plant conservation in madagascar using red list criteria : rare and threatened pandanaceae indicate sites in need of protection. Oryx 41: 168–176.

Cordellier, M. and Prenninger, M. 2009. Inferring the past to predict the future: climate modelling predictions and phylogeography for the freshwater gastropod, *Radix balthica* (Pulmonata, Basommatophora). Molecular Ecology 18: 534–544.

Elithet, A. L. 2006. Novel methods improve prediction of species ' distributions from occurrence data. Ecography 2: 129–15.

Hijmans, R. J.; Cameron, S. E; Para, J. L.; Jones, P. G. and Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.

Hijmans, R. J.; Guarino, L.; Cruz, M. and Rojas, E. 2001. Computer tools for spatial analysis of plant genetic resources data : 1 . DIVA-GIS. Plant Genetic Resources Newsletter 127: 15-19.

IPCC. 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; van der Linden, P.J. and Hanson,C.E., Editors). Cambridge University Press, Cambridge, U.K. 976 pages.

Iverson, L. R. and Prasad, A. M. 2001. Projected effects of climate change on patterns of Vertebrate and tree species richness in the conterminous United States. Ecosystems 4: 216–225.

Khuraijam, J. and Singh, R. 2015. Ethnobotany of *Cycas pectinata* Buch. Ham. in Northeast India. Encephalartos 119: 18-23.

Kumar, S. and Stohlgren, T. J. 2009. Maxent Modeling for predicting suitable habitat for threatened and endangered tree canacomyrica monticola in new caledonia. Journal of Ecology and Natural Environment 1: 94–98.

Marti, E.; Peterson, A. T.; Servi, J. I. and Kiff, L. F. 2006. Ecological niche modelling and prioritizing areas for species reintroductions. Oryx 40: 411–418.

Mihoub, J.B.; Jiguet, F.; Lecuyer, P.; Eliotout, B. and Sarrazin, F. 2014. Modelling nesting site suitability in a population of reintroduced eurasian black vultures, *Aegypius monachus* in the Grands Causses, France. Oryx 48: 116–124.

Moss, R.H.; Edmonds, J.A.; Hibbard, K.A.; Manning, M.R.; Rose, S.K.; Van vuuren, D.P.; Carter, T.R.; Emori, S.; Kainuma, M.; Kram, T.; Meehl, G.A.; Mitcell, J.F.B.; Nakicenovic, N.; Riahi, K.; Smith, S.J.; Stouffer, R.J.; Thomson, A.M.; Weyant, J.P .and Wilbanks, T.J. 2010. The next generation of scenarios for climate change research and assessment. Nature 463: 747–756.

Nagalingum, N.S.; Marshall, C.R.; Quental, T.B.; Rai, H.S.; Little, D.P. and Mathews, S. 2011. Recent synchronous radiation of a living fossil. Science 334(6057): 796-799. http://doi.org/10.1126/science.1209926

Nguyen, A. 2010. *Cycas pectinata*. The IUCN red list of threatened species 2010: e.t42062a10617695. http://dx.doi.org/10.2305/iucn.uk.2010-3.rlts.t42062a10617695.en

Pearson, R.G.; Raxworthy, C.J.; Nakamura, M. and Peterson, A.T. 2007. Predicting species distributions from small numbers of occurrence records : a test case using cryptic geckos in Madagascar. Journal of Biogeography 34: 102–117.

Peterson, A.T. 2006. Uses and requirements of ecological niche models and related distributional models. Biodiversity Informatics 3: 59–72.

Phillips, J.S. and Dudik, M. 2008. Modeling of species distributions with maxent : new extensions and a comprehensive evaluation. Ecography 31: 161–175.

Phillips, S.J.; Anderson, R.P. and Schapire, R. E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Engineering 190: 231–259.

Prathapan, K.D. 2006. Conservation of cycads in India. Current Science 91: 862–863.

Singh, K.J. and Singh, R. 2014. Population assessment and distribution of *Cycas pectinata* Buchanan-Hamilton in Northeast India. Pleione 8: 17–25.

Svenning, J. C.; Kerr, J.; Rahbek, C. 2009. Predicting future shifts in species diversity. Ecography 32: 3–4.

Thomas, C.D.; Cameron, A.; Green, R.E.; Bakkenes, M.; Beaumont, L.J.; Collingham, Y.C.; Erasmus, B.F.N.; Siqueira, M.F.; Grainger, A.; Hannah, L.; Hughes, L.; Huntley, B.; Jaarsveld, A.S.; Midgley, G.F.; Miles, L.; Ortega-Huerta, M.A.; Peterson, A.T.; Phillips, O.L.and Williams, S.E. 2004. Extinction risk from climate change. Nature 427: 145–148.

Thompson, I.; Mackey, B.; Mcnulty, S. and Mosseler, A. 2009. Forest Resilience, Biodiversity, and Climate Change. A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems. CBD Technical Series no. 43. Secretariat of the Convention on Biological Diversity, Montreal. 67 pages.

Thuiller, W.; Lavorel, S.; Araujo, M. B.; Sykes, M. T. and Prentice, I. C. 2005. Climate change threats to plant diversity in Europe. Proceedings of the National Academy of Sciences 102: 8245–8250.

UNEP-WCMC. 2012. Data Standards for the World Database on Protected Areas. UNEP=WCMC., U.K. 15 pages.

Upadhaya, K.; Thapa, N.; Lakadong, N.J.; Barik, S.K. and Sarma, K. 2016. Priority areas for conservation in northeast india : a case study in Meghalaya based on plant species diversity and endemism. International Journal of Ecology and Environmental Sciences 39: 125–136.

Warren, D.L.; Glor, R.E. and Turelli, M. 2010. Enmtools: a toolbox for comparative studies of environmental niche models. Ecography 33: 607–611.

Received 12 February 2017
Accepted 21 June 2017

Also see Supplementary Material:

Supplementary Table 1:
Correlation between different bioclimatic variables (pages 136-137)

Supplementary Table 2:
List of Protected Areas identified suitable under climate change scenario, 2050 (pages 138-141)

Pradhan, Aditya and Chettri, Arun. 2017. Identifying Protected Areas Suitable for Conservation of *Cycas pectinata* Buch. Ham. **in Southeast Asia Under Climate Change Scenario. International Journal of Ecology and Environmental Sciences 43 (2): 129-135.**

Supplementary Table 1: Correlation between different bioclimatic variables

Variables	bio_19.asc	bio_1.asc	bio_2.asc	bio_3.asc	bio_4.asc	bio_5.asc	bio_6.asc	bio_7.asc	bio_8.asc	bio_9.asc
bio_19.asc	0	0.4047379	-0.48755	0.700346	-0.50357	0.139581	0.501064	-0.56343	0.204622	0.431746
bio_1.asc	0	0	-0.45718	0.662544	-0.80689	0.823307	**0.967323**	-0.79074	0.772237	**0.923385**
bio_2.asc	0	0	0	-0.34707	0.49677	-0.16068	-0.56403	0.632321	-0.30698	-0.42042
bio_3.asc	0	0	0	0	-0.85567	0.251654	0.768334	-0.84379	0.363495	0.682544
bio_4.asc	0	0	0	0	0	-0.34749	-0.91799	**0.983038**	-0.41166	-0.83817
bio_5.asc	0	0	0	0	0	0	0.666257	-0.31249	0.789205	0.703784
bio_6.asc	0	0	0	0	0	0	0	-0.91658	0.657527	**0.934306**
bio_7.asc	0	0	0	0	0	0	0	0	-0.4144	-0.81277
bio_8.asc	0	0	0	0	0	0	0	0	0	0.506044
bio_9.asc	0	0	0	0	0	0	0	0	0	0
bio_10.asc	0	0	0	0	0	0	0	0	0	0
bio_11.asc	0	0	0	0	0	0	0	0	0	0
bio_12.asc	0	0	0	0	0	0	0	0	0	0
bio_13.asc	0	0	0	0	0	0	0	0	0	0
bio_14.asc	0	0	0	0	0	0	0	0	0	0
bio_15.asc	0	0	0	0	0	0	0	0	0	0
bio_16.asc	0	0	0	0	0	0	0	0	0	0
bio_17.asc	0	0	0	0	0	0	0	0	0	0
bio_18.asc	0	0	0	0	0	0	0	0	0	0

Note: *The variables having correlation value of > 0.9 (Highlighted in light green colour) were discarded and thus out of 19 bioclimatic v*

bio_10.asc	bio_11.asc	bio_12.asc	bio_13.asc	bio_14.asc	bio_15.asc	bio_16.asc	bio_17.asc	bio_18.asc
0.2311094	0.464303	0.697586	0.4448484	0.82631937	-0.4671693	0.4631316	0.836647	0.352579
0.8941257	**0.973312**	0.64216	0.6148752	0.36851284	-0.067771	0.6273461	0.3952303	0.379744
-0.3146692	-0.49678	-0.69396	-0.5393188	-0.5307325	0.5456221	-0.5680931	-0.5545964	-0.57284
0.34749223	0.768215	0.730075	0.5287683	0.68887777	-0.2040828	0.5590515	0.7048085	0.406831
-0.4587275	-0.9204	-0.72623	-0.6411065	-0.4676416	0.1028423	-0.6662359	-0.4957626	-0.46038
0.97942287	0.680145	0.273926	0.3263257	0.09800784	0.0300599	0.3196225	0.1124879	0.055044
0.76326004	**0.995708**	0.729433	0.6564173	0.46789492	-0.1546845	0.6762287	0.4967588	0.442293
-0.4470889	-0.90366	-0.78229	-0.6611844	-0.5434649	0.2131596	-0.690015	-0.5724682	-0.53389
0.84345724	0.667873	0.443941	0.4635132	0.23168077	0.0756296	0.4629311	0.24555	0.348698
0.7597992	**0.936437**	0.594471	0.5444586	0.36427283	-0.1446431	0.5602822	0.3924096	0.284085
0	0.769432	0.412088	0.4354209	0.20202203	-0.026176	0.4341562	0.2204146	0.206967
0	0	0.704326	0.6526378	0.42608897	-0.089083	0.6703422	0.4545049	0.424262
0	0	0	0.8727517	0.70826562	-0.2990767	**0.9073305**	0.7348436	0.793722
0	0	0	0	0.34049011	0.0536709	**0.9903081**	0.3712852	0.727548
0	0	0	0	0	-0.5764669	0.383217	**0.9955056**	0.459636
0	0	0	0	0	0	0.0039387	-0.5804273	-0.15353
0	0	0	0	0	0	0	0.4145689	0.762373
0	0	0	0	0	0	0	0	0.481979
0	0	0	0	0	0	0	0	0

ariables, 11 variables were used for modeling.

Pradhan, Aditya and Chettri, Arun. 2017. Identifying Protected Areas Suitable for Conservation of *Cycas pectinata* Buch. Ham. in Southeast Asia Under Climate Change Scenario. International Journal of Ecology and Environmental Sciences 43 (2) 129-135.

Supplementary Table 2: List of Protected Areas identified suitable under climate change scenario, 2050

COUNTRY	PROTECTED AREA	IUCN Management category	Type of protected area	Designiation Type
BANGLADESH				
	Hajarikhil	II	Wildlife Sanctuary	National
	Baroiyadhala	II	National Park	National
	Rema Kalenga	II	Wildlife Sanctuary	National
	Barshijora Eco-Park	Not reported	Eco Park	National
BHUTAN				
	Royal Manas	II	National Park	National
	Khaling	IV	Wildlife Sanctuary	National
	Phipsoo	IV	Wildlife Sanctuary	National
	Biological Corridor 3	VI	Biological Corridor	National
	Biological Corridor 5	VI	Biological Corridor	National
CHINA				
	Nanxi	VI	Nature Reserve	National
	Yuanjiang	VI	Nature Reserve	National
	Amushan	V	Nature Reserve	National
	Xishuangbanna	Not Applicable	UNESCO-MAB Biosphere Reserve	International
	Mofanghe	Not Applicable	Nature Reserve	National
	Menglianlongshan	V	Nature Reserve	National
	Weiyuanjiang	V	Nature Reserve	National
	Zhangmuqing	V	Nature Reserve	National
	Laoheishan	V	Nature Reserve	National
	Dazhongshan	V	Nature Reserve	National
	Xintian (Dabanbi)	V	Nature Reserve	National
	Gancha	V	Nature Reserve	National
	Zhangba	V	Nature Reserve	National
	Huanglianshan	V	Nature Reserve	National
	Caiyanghe	V	Nature Reserve	National
	Nanjianfenghuangshan	V	Nature Reserve	National
	Tongbiguan	V	Nature Reserve	National
	Nangunhe	V	Nature Reserve	National
	Zixishan	V	Nature Resserve	National
	Gaolushan	V	Nature Reserve	National
	Shanhouchachang	V	Nature Reserve	National
	Hongshiyanshuiyuan	V	Nature Reserve	National
	Mopanshan	V	Nature Reserve	National
	Nanjiantulin	V	Nature Reserve	National
	Ruilijangliuyu	V	Nature Reserve	National
	Dedanghoushanshuiyuanlin	V	Nature Reserve	National
	Niuluohe	V	Nature Reserve	National
	Pengzhuyulaiju	V	Nature Reserve	National
	Yongdedaxueshan	V	Nature Reserve	National
	Ailaoshan	V	Nature Reserve	National
	Xueshanheshuiyuanhanyanglin	V	Nature Reserve	Mnational
	Jizushan	V	Nature Reserve	National
	Yunling	V	Nature Reserve	National
	Yunlongtianchi	V	Nature Reserve	National

	Shibaoshan	V	Nature Reserve	National
	Cibihu	V	Nature Reserve	National
	Niaodiaoshan	V	Nature Reserve	National
	Cangshanerhai	V	Nature Reserve	National
	Hudiequan	V	Nature Reserve	National
	Nanxi	V	Nature Reserve	National
	Amushan	V	Nature Reserve	National
	Panzhihuasutiesutie	V	Nature Reserve	National
	Mofanghe	V	Nature Reserve	National
	Zhangmuqing	V	Nature Reserve	National
	Laoheishan	V	Nature Reserve	National
	Huafushan	V	Nature Reserve	National
	Dazhongshan	V	Nature Reserve	National
	Shizishan	V	Nature Reserve	National
	Xintian (Dabanbi)	V	Nature Reserve	National
	Gancha	V	Nature Reserve	National
	Zhangba	V	Nature Reserve	National
	Huanglianshan	V	Nature Reserve	National
	Caiyanghe	V	Nature Reserve	National
	Zixishan	V	Nature Reserve	National
	Tanhuashan	V	Nature Reserve	National
	Gaolushan	V	Nature Reserve	National
	Shanhouchachang	V	Nature Reserve	National
	Hongshiyanshuiyuan	V	Nature Reserve	National
	Mopanshan	V	Nature Reserve	National
	Niuluohe	V	Nature Reserve	National
	Pengzhuyulaiju	V	Nature Reserve	National
	Diaolingshan	V	Nature Reserve	National
	Ailaoshan	V	Nature Reserve	National
	Fanjia	V	Nature Reserve	National
	Jiaxi	V	Nature Reserve	National
	Wuzhishan	V	Nature Reserve	National
	Songtao shuiziyuan	V	Nature Reserve	National
	Shahe shuiziyuan	V	Nature Reserve	National
COMBODIA				
	Samlaut	VI	Multiple use Management Area	National
	Central Cardamom Mountains	IV	Protected Forest	National
INDIA				
	Barail	IV	Sanctuary	National
	Barnadi	IV	Sanctuary	National
	Barsey Rhododendron	IV	Sanctuary	National
	Buxa	IV	Sanctuary	National
	D Ering Memorial (Lali)	IV	Sanctuary	National
	Dampa	IV	Sanctuary	National
	Dibru	Not Reported	Sanctuary	National
	Fakim	IV	Sanctuary	National
	Fambong Lho	IV	Sanctuary	National
	Garampani	IV	Sanctuary	National
	Garumara	IV	Sanctuary	National
	Gumti	IV	Sanctuary	National
	Intanki	IV	Sanctuary	National
	Itanagar	IV	Sanctuary	National
	Jaldapara	IV	Sanctuary	National
	Kaziranga	II	National Park	National
	Kaziranga National Park	Not Applicable	World Heritage Site	International
	Keibul Lamjao	II	National Park	National
	Khawnglung	II	National Park	National
	Lawkhowa	IV	Sanctuary	National
	Loktak Lake	Not Reported	Ramsar Site	International
	Mahananda	IV	Sanctuary	National
	Manas	IV	Sanctuary	National
	Manas Wildlife Sanctaury	Not Applicable	World Heritage Site	International

	Mouling	II	National Park	National
	Murlen	II	National Park	National
	Namdapha	Not Reported	Sanctuary	National
	Nameri	IV	Sanctuary	National
	Nongkhyllem	IV	Sanctuary	National
	Orang	IV	Sanctuary	National
	Pabitori	IV	Sanctuary	National
	Pakke (Pakhui)	IV	Sanctuary	National
	Puliebadze	IV	Sanctuary	National
	Rangapahar	IV	Sanctuary	National
	Roa	IV	Sanctuary	National
	Sessa Orchid	IV	Sanctuary	National
	Sonia Rupia	IV	Sanctuary	National
	Yangoupokpi-Lokchao	IV	Sanctuary	National
LAOS				
	Corridor Nakai - Nam Theun and Phou Hin Poun	VI	National Biodiversity Conservation Area	National
	Dong Phou Vieng	VI	National Biodiversity Conservation Area	National
	Nakai - Nam Theun	VI	National Biodiversity Conservation Area	National
	Nam Chuane	Not Reported	Conservation Area	National
	Nam Et	VI	National Biodiversity Conservation Area	National
	Nam Ha	VI	National Biodiversity Conservation Area	National
	Nam Kading	VI	National Biodiversity Conservation Area	National
	Nam Kan	Not Reported	Not Reported	National
	Nam Pouy	VI	National Biodiversity Conservation Area	National
	Nam Theun Ext.	VI	National Biodiversity Conservation Area	National
	Phou Dene Din	VI	National BiodiversityConservation Area	National
	Phou Khao Khoay	VI	National Biodiversity Conservation Area	National
	Phou Loey	VI	National Biodiversity Conservation Area	National
	Phou Theung	Not Reported	Not Reported	National
	Phou Xang He	VI	National Biodiversity Conservation Area	National
	Xe Xap	Not Reported	Not Reported	National
MYANMAR				
	Htamanthi	IV	Wildlife Sanctuary	National
	Hukaung Valley (Extension)	IV	Tiger Reserve	National
	Indawgyi Lake	IV	Wildlife Sanctuary and ASEAN Heritage Park	National
	Loimwe	Not Reporeted	Proected area	National
	Nam Lang	Not Reported	Not Reported	National
	Par Sar	Not Reported	Protected arae	National
	Pidaung	IV	Wildlife Sanctuary	National
	Pyin-O-Lwin	IV	Bird Sancturay	National
	Taung Gyi	IV	Bird Sancturay	National
NEPAL				
	Shivapuri-Nagarjun	II	National Park	nATIONAL
	Phulchoki	Not Reported	Conservation Area	National
THAILAND				
	Chalearm Rattanakosin	II	National Park	National
	Chiang Dao	Ia	Wildlife Sancturay	National
	Doi Wiang Pha	Ia	Wildlife Sancturay	National
	Khao Khitchakut	II	National Park	National
	Khao Chamao Khao Wong	II	National Park	nATIONAL

			National Park and ASEAN	
	Khao Yai	II	Heritage Park	National
	Khao Angruenai	Ia	Wildlife Sanctuary	National
	Khao Sib Ha Chan	II	National Park	National
	Khao Soi Dao	Ia	Wildlife Sanctuary	National
	Khlong Kruewai Chalearn Phrakiat	Ia	Wildlife Sanctuary	National
	Khun Chae	II	National Park	National
	Khun Nan	II	National Park	National
	Mae Phang	II	National Park	National
	Na Haew	II	National Park	National
	Samoeng	Ia	Wildlife Sanctuary	National
VIETNAM				
	A Yun Pa	Not Reported	Nature Reserve	National
	An Toan	Not Reported	Nature Reserve	National
	Bidoup Nui Ba	Not Reported	National Park	National
	Chu Hoa	Not Reported	Nature Reserve	nATIONAL
	Chu Yang Sin	II	National Park	National
	Copia	Not rEPORTED	Nature Reserve	National
	Dak Mang	Not vReported	Nature Reserve	National
	Dak Uy	Not vReported	Nature Reserve	National
	Deo Ngoau Muc	IV	Nature Reserve	National
	Ea so	Not Reported	Nature Reserve	National
	Ho Lak	VI	Culture and Historical Site	National
	Hon Ba	Not Reported	Nature Reserve	National
	Kalon Song Mao	IV	Nature Reserve	National
	Kon Chu Rang	IV	Nature Reserve	National
	Kon Ka Kinh	II	National Park	National
	Muong Nhe	IV	Nature Reserve	National
	Muong Phang	Not Reported	Cultural and Historical Site	National
	Nam Don	IV	Nature Reserve	National
	Nam Ka	IV	Nature Reserve	National
	Nam Nung	IV	Nature Reserve	National
	Ngoc Linh (Quang Nam)	Not Reported	Nature Reserve	National
	Nui Ong	IV	Nature Reserve	National
	Phuoc Binh	II	National Park	National
	Pu Hoat	Not Reported	Nature Reserve	National
	Pu Huong	IV	Nature Reserve	National
	Pu Mat	II	National Park	National
	Rung Thong Da Lat	VI	Cultural and Historical Site	National
	Sop Cop	IV	Nature Reserve	National
	Ta Dung	Not Reported	Nature Reserve	National
	Ta Kou	IV	Nature Reserve	National
	Trap Kso	Not Reported	Nature Reserve	National