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# Climate-Driven Distribution Modelling and Conservation Prioritization of Endemic Plants (Ceropegia, Kalanchoe, Araceae) in Vidharbha Region: A Review

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**Abstract--** The influence of changing climate is now becoming evident in terms of shifting species' distributions, which presents considerable difficulties for the preservation of the native plant species. In the Vidarbha area of the state of Maharashtra, India, there are some endemic and endangered species such as Ceropegia, Kalanchoe, and Araceae. The present work is dedicated to the prediction of the possible effects of future climatic changes on the distribution patterns of these endemic species and the selection of priority areas for the conservation of biodiversity. The data on the distribution of the selected species was collected from field observations, herbaria, and scientific literature, whereas climatic and environmental variables were extracted from global climate databases. The ecological niche modeling approach was applied for predictions of current and future habitat suitability under different climate change scenarios. Moreover, additional spatial analysis was performed for evaluating habitat shift, range reduction, and species richness of endemic plants. It was revealed that the habitats of many of these species might be considerably reduced and shifted geographically in future climatic conditions. Conservation prioritization analysis identified some refuges of biodiversity that will remain suitable for the survival of many species in the future. The research underscores the necessity of the integration of species distribution models into conservation priorities to ensure that endemic plants are protected from the increasing risks of climate change.

**Keywords--** Climate, Endemic species, Global biodiversity, Distribution & Conservation, Vidarbha Region,

## I. INTRODUCTION

Global warming is becoming a major factor in the loss of biodiversity around the world and affecting distribution of species, their ecology, and the suitability of their habitat. Increasing global warming has affected the ecology of species, causing change in precipitation and extreme weather conditions that affect the ecological niche and pose threats for the survival of many plant species especially those species which have a limited geographical range. The endemic plant species are at greater risk because of their specialization in habitat requirements and limited distribution.

India is considered to be one of the megadiverse countries in the world with a variety of endemic flora in different biogeographical zones of the country. The state of Vidarbha in the state of Maharashtra is an ecologically important zone with tropical dry deciduous forest, hills, plateau, and riverine habitats. Despite being an ecologically important zone, it is facing various pressures like climate change, habitat loss, agriculture, urbanization, and mining, posing risks to many endemic plant species.

The plant species of Ceropegia and Kalanchoe genera, as well as the plants from the Araceae family, which are native to peninsular India, have significant ecological, evolutionary, and conservation value. Ceropegia plant species are distinguished by their exceptional adaptation to specific pollination and limited distribution, whereas many Kalanchoe plant species are known for being adapted to droughts. At the same time, endemic Araceae plant species are significant for regional biodiversity and ecosystems owing to their habitat specificity. Nevertheless, these plants have fragmented distributions and are at risk due to climate-driven habitat changes.

Species Distribution Modeling (SDM) has emerged as an important approach in analyzing the consequences of climate change for biodiversity. By using the data about the distribution of a particular species and its environment, it is possible to make predictions concerning the distribution of the species under different climatic conditions. In addition, SDMs can help to reveal range contraction, range expansion, habitat fragmentation, and climate refugia. This information is crucial for making decisions in favor of biodiversity conservation.

The Conservation Prioritization framework is a method which uses the ecological information, species richness, predictions of habitat suitability and threat to recognize areas of conservation value. In the case of endemics of plant, the framework helps in the optimal use of the scarce resources by emphasizing the importance of critical habitats which protect the species. Thus, the combination of distribution modeling of the plants due to climate changes and Conservation Prioritization gives an effective approach towards the development of the management strategies aimed at avoiding future extinction of species.



The purpose of the current research is to examine the influence of climate change on the potential distribution of endemic *Ceropegia*, *Kalanchoe* and some selected *Araceae* species in the region of Vidarbha through the species distribution modeling approach. Additionally, this study aims to find out the priority areas for conservation based on the predictions of habitat suitability and species persistence under future climate conditions.

## II. LITERATURE REVIEW

Climate change has come up to be one of the most important challenges to the biodiversity of the world affecting the distribution of the species, their functions within ecosystems and even extinction risks. Species with limited ranges geographically and ecologically tend to be more prone to any changes in climate. Endemic species tend to have limited capacities of dispersion and are adapted to very specific habitats making them vulnerable to changes in climate and precipitation. Thus the need has become to understand the impact of climate change scenarios on endemic plants. Species Distribution Models (SDMs) have gained popularity recently to forecast the future habitat suitability and assist conservation efforts.

The Species Distribution Modelling makes use of records on species occurrences and environmental variables to understand the ecological niche of the species. MaxEnt is among the most popular models used due to their high efficacy when dealing with presence-only datasets and small samples of data, typical for rare and endemic plant species. Recent reviews state that SDMs are becoming important in climate change impact assessment and biodiversity conservation. Nonetheless, concerns regarding model assumptions, sampling bias, and future climate projections are still pertinent in conservation-related studies.

In India, there have been various studies that used SDMs to explore the influence of climate change on endemic and endangered plants. Studies done on endemic plant species in biodiversity hotspots have shown that increases in temperature and changes in rainfall could result in serious habitat contractions and shifts. Modelling studies have shown that many endemic species would be faced with habitat losses, fragmentation of their ranges and become more extinction prone in future climates. This shows the importance of taking future climate projections into account when developing plans for conservation and recovery of species.

Some recent studies that were done on endemic plant species in peninsular India have shown that SDMs can be used to identify suitable habitats in the future.

For instance, climate-driven modeling of the endemic orchid *Habenaria grandifloriformis* showed large changes in suitable habitats under different SSPs. This has shown that future climate conditions could change the distribution of this species. Also, studies on endemic plant groups in Western Ghats have shown that elevation, temperature, rainfall, and microhabitats play crucial roles in species distributions.

The genus *Ceropegia* belongs to the most valuable endemics of flowering plants from India. The majority of species has very narrow habitat ranges and specific pollination mechanisms. Habitat loss, excessive harvesting, and global warming have caused declines in the population size of several species within this genus. Studies related to ecological niche modeling of *Ceropegia* species prove the potential of remote sensing and geospatial approaches for finding proper habitat range and conservation of endangered areas. According to these findings, climatic conditions play a significant role in the species' distribution.

The genus *Kalanchoe* unites several lithophytic and endemic species adapted to life in rocky outcrops and seasonally dry climates. Despite the lack of climate-based models for Indian endemic *Kalanchoe* species, studies on endemic herbaceous vegetation of rocky habitats prove that changes in temperature and moisture level can largely impact habitat suitability. Rocky plateaus and hill ecosystems, where most of the *Kalanchoe* species grow, are regarded as fragile ecosystems in need of special conservation efforts due to climate change.

Species from the family *Araceae* also form an important part of India's endemic flora, ecologically. Endemic aroids often inhabit moist forests, wetlands, and other unique ecosystems that are highly vulnerable to climate changes. While there are not many studies about the influence of climate factors on the geographical distributions of endemic *Araceae* species in India, the analysis of endemic tropical plants from other families shows that habitat suitability is tightly connected with the climate and topographical factors. Possible changes in the habitat suitable for endemics would require the development of some adaptation strategies, such as habitat connectivity and climate refugia protection.

One of the most ecologically valuable regions of Maharashtra is Vidarbha where one can find dry deciduous forests, hill ranges, plateaus, and other fragmented habitats. In spite of the importance of this region from the botanical point of view, only a few studies consider possible climate effects on the endemic plants' distributions. At present, most biodiversity assessment studies include species inventorying and observations, but climate-driven modelling of endemics' distributions has not been sufficiently studied yet.



Taking into account increased frequency of droughts and higher temperatures in central India, endemic plants from Vidarbha may be threatened in the future.

The prioritization of conservation has emerged as one of the most important uses of species distribution models. Through the integration of habitat suitability predictions in the future with the analysis of biodiversity hot spots, networks of protected areas, and landscape connectivity, scientists are able to determine areas that have the most potential for maintaining species in the future. In recent studies, there is recognition of the importance of including not only current species distribution, but also future climate refuges where species may survive in future climatic conditions.

### III. RESEARCH GAP

While SDMs have extensively been used to evaluate the effect of climate change on endemic plant species in global and Indian biodiversity hotspots, very few studies have attempted to do the same for endemic species in Vidarbha. Moreover, there seems to be no study that has evaluated the effect of climate change on the distributions and conservation of endemic species from the genera *Ceropegia*, *Kalanchoe*, and *Araceae*. Therefore, it is imperative to conduct an integrated study using these parameters for the aforementioned groups..

### IV. METHODOLOGY:

The experiment takes place in the Vidarbha area in the eastern part of the state of Maharashtra in India. The region includes the districts of Nagpur, Wardha, Chandrapur, Gadchiroli, Bhandara, Gondia, Amravati, Akola, Yavatmal, Washim, and Buldhana. It is noted for its tropical dry deciduous forests, plateau, hills, wetlands, and cultivated areas. The climate is tropical, with hot summer months, rainy season, and cool winter. There exist many rare plant species endemic to this area, such as those belonging to *Ceropegia*, *Kalanchoe*, and *Araceae* genera.

#### *Selection of Target Species:*

Endemic representative species of the genera *Ceropegia*, *Kalanchoe*, and the family *Araceae* that are found within or in the vicinity of the region of Vidarbha will be selected as target taxa in the current study. These taxa were chosen because they are some of the significant floral elements of the Deccan Plateau and the Western Ghats-Central Indian transitional zone, which include species having narrow distribution ranges, habitat specialization, and differing conservation statuses. The following criteria will be used in selecting species to make sure of the scientific credibility and relevance of the study to ecological niche modeling.

The first criterion will be the endemism status of the species in question. It is preferred that the species are endemic to India and even more specifically Maharashtra, the Deccan Plateau, or Central India as they are more vulnerable to any kind of habitat disruption and climatic changes due to their narrow distribution ranges.

The second criterion is the existence of accurate occurrence records. Those species that have enough georeferenced records will be chosen from sources such as herbarium collections, floristic studies, databases on biodiversity, and field observations. This criterion will ensure that there are enough data for building good ecological niche models and minimize uncertainties in the space as well as in statistics when making a model.

Importance of conservation of each species will be evaluated during choosing the species. Those species that are classified as threatened, endangered, vulnerable, and data deficient on the national or international level, for example, on the IUCN Red List and in the literature on conservation in regions, will be prioritized. Also, ecological importance, rarity, and susceptibility to habitat destruction will be taken into account.

Another key criterion in selecting a candidate species for analysis is the presence of adequate geographic data for ecological niche modeling. The species should have enough occurrence records across space to allow for habitat suitability modeling with algorithms like MaxEnt. If species lack occurrence records in large numbers or if the records available do not satisfy the minimum criteria for model fitting and validation, then those particular species could be left out from the analysis.

In order to ensure consistency in taxonomic treatments and to prevent any potential taxonomic error due to synonymy or old classification systems, taxonomic treatment and nomenclature of species will be done using recognized floristic databases and recent taxonomic works. Scientific names and their synonyms, authorships and taxonomic statuses of species will be confirmed by means of standard references like World Flora Online (WFO), Plants of the World Online (POWO), International Plant Names Index (IPNI) and publications from Botanical Survey of India (BSI), along with regional floras and peer-reviewed taxonomic studies.

#### *Species Occurrence Data Collection*

Occurrences of the species will be obtained from various sources in order to achieve complete geographic coverage and reliable data for ecological niche modelling. Occurrences will first be obtained through field surveys conducted in the Vidarbha region where the species will be identified and recorded. The locations will then be georeferenced using the Global Positioning System (GPS).



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After that, georeferencing of the occurrences of the species obtained from herbarium specimens will be conducted where the data will have been officially validated. Other sources of occurrence will be peer-reviewed scientific literature including surveys and taxonomical articles. Moreover, georeferenced data will be obtained through Global Biodiversity Information Facility (GBIF). This will help to obtain open-access data from various institutions in the world concerning biodiversity. Verified distribution records from Botanical Survey of India (BSI) and other regional biodiversities databases will also be used where necessary. Using different sources of data will help to obtain robust and representative data for conducting ecological niche modelling.

The geographic coordinates will be checked and standardized through Geographic Information System (GIS) software..

#### V. ENVIRONMENTAL VARIABLES

The occurrence of plant species is greatly governed by climatic, topographic, and edaphic factors. Hence, a suite of environmental predictor variables will be used to predict the ecological niche and potential distributions of the selected endemic plant species of Ceropegia, Kalanchoe, and Araceae family found in the Vidarbha region. The environmental variables will be chosen based on the ecological significance of plant life in relation to growth, survival, and distributions as well as the ability to model species distribution.

Long-term climatic variables of temperature and precipitation will be downloaded from WorldClim Version 2.1 dataset at a spatial resolution of 30 arc seconds (approx. 1 km<sup>2</sup>). The variables are a representation of climate extremes and seasonality and play an important role in determining the physiology of a species. The climatic predictors include annual mean temperature, temperature seasonality, temperature of the warmest month, temperature of the coldest month, annual precipitation, precipitation seasonality, precipitation of the wettest quarter, and precipitation of the driest quarter. These variables are known to determine the distribution of plants since they govern the process of germination, flowering, dormancy, and physiological stress.

In addition to the climatic parameters, other topographic and environmental layers will be employed to enhance the predictive power of the model. The elevation layer will be employed based on digital elevation models (DEMs), due to the fact that altitude impacts climatic conditions, soil moisture and vegetation patterns in the area under consideration.

Terrain variables such as slope and aspect will be used, since these determine solar radiation levels, drainage conditions, soil moisture and microclimates. Anthropogenic impacts, habitat fragmentation and vegetation type will be included via land use and cover data layers. Soils layers will be employed where appropriate and where good datasets exist since soil variables impact on plant establishment and nutrient availability.

All environmental variables will be tested for multicollinearity prior to developing the models. Pearson's correlation coefficient will be calculated for all pairs of variables. Those variables showing a high level of correlation (correlation coefficients greater than 0.70;  $|r| > 0.70$ ) will be considered to have a very strong linear relationship. From the group of correlated variables, the one which is ecologically significant will be selected..

#### *Climate Change Scenarios*

To assess possible effects of climate change on the possible future distribution of endemic plant species, future climatic data sets will be derived from the Coupled Model Intercomparison Project Phase 6 (CMIP6) data sets, which are standardized climate simulations provided by the global climate modelling community. CMIP6 data is considered the most advanced version of climate models that constitute the scientific foundation of the IPCC Sixth Assessment Report.

Projections of future habitat suitability will be made using three Shared Socioeconomic Pathways (SSP) scenarios, each corresponding to specific greenhouse gas emissions and socio-economic developments. In particular, SSP1-2.6 corresponds to the sustainable development scenario, marked by low greenhouse gas emissions and effective climate mitigation actions. SSP2-4.5 corresponds to the moderate scenario with moderate greenhouse gas emissions and balanced socio-economic development. SSP5-8.5 corresponds to the high emissions scenario marked by rapid economic development driven by fossil fuels and inadequate climate mitigation policies.

Future climate scenarios will be developed for two future time slices: 2041-2060 (generally known as the 2050s), and 2061-2080 (2070s). Comparison of present and future suitability of habitats within the context of multiple SSPs will help us evaluate range shifts, habitat stability, and vulnerability of endemic species.

#### *Species Distribution Modelling*

The prediction of habitat suitability for plant species distribution will be done through the use of the Maximum Entropy (MaxEnt) algorithm, which is the most common method of machine learning applied in species distribution modelling with occurrence data only.

MaxEnt is well adapted to endemic and rare species because it provides good results on small sample sizes and gives robust predictions of habitat suitability. MaxEnt calculates the probability distribution of maximum entropy based on the constraints imposed by environmental factors of the known locations of species.

The species distribution modelling will start with the creation and verification of occurrence datasets for different plant species collected from field observations, herbarium data, biodiversity data and scientific literature. These occurrences will be combined with the chosen environmental variables to reveal connections between the presence of the species and environmental variables. For the assessment of the model predictive performance, occurrence data will be randomly split into a training set (75%) and a testing set (25%). The first subset will be used to build the model, while the second will be used for its independent validation. Model replication will be achieved by applying cross-validation methods. The output produced will include continuous habitat suitability maps indicating the likelihood of suitable environment for the species in question.

To gauge the performance of the model, a variety of statistical indicators will be used. For instance, the Area under the ROC curve (AUC) will indicate how good is the discriminative power of the model, while the True Skill Statistic (TSS) will give an indication on the accuracy of predictions. Other statistics that will be used to test model performance include sensitivity and specificity statistics. The habitat suitability index generated from MaxEnt will be categorized into four classes including unsuitable, low suitability, moderate suitability and high suitability.

#### *Assessment of Climate-Induced Distribution Changes*

The maps showing the habitat suitability of the selected endemic species in relation to the existing and future climatic conditions will be compared to assess the impact of climate change on the geographic distribution of the selected species. The spatial analysis of the results will involve measuring habitat gains, habitat losses, range expansion, range contraction, and the shifting of the geographic position of the habitats in relation to different climate conditions.

Spatial overlaying using GIS techniques is used to calculate differences in the habitat sizes under the existing and future conditions. Suitable habitat sizes will be measured for each scenario and the percentage increase and decrease in the habitat size will be calculated. Vulnerability of species to the impacts of climate change will be measured by the extent of habitat loss, fragmentation, and displacement. Species likely to suffer from habitat reduction and shift in geographic positions will be identified as more vulnerable.

#### *Conservation Prioritization*

Prioritizing conservation sites is one of the primary objectives of this research project. Conservation planning will involve several aspects of ecology, including current habitat suitability, future habitat suitability, species diversity, endemic concentration, landscape connectivity, and distribution of protected areas.

For prioritization of spatial locations, conservation planning methods will be used through GIS analysis. The locations having potential for harboring many endemics in present and future climatic conditions will be categorized as high priority conservation regions. In order to evaluate the landscape connectivity, it will be determined which areas will act as ecological corridors in facilitating movement and gene flow of species under different climatic conditions. Protected areas will be analyzed in terms of whether they are covering the suitable habitat now and in future..

#### *Validation and Sensitivity Analysis*

In order to make sure that the predictions of the models are reliable and robust, the process of repeated cross validation will be carried out during the process of building models. In addition, sensitivity analysis will also be performed in order to study the effects of model outputs using different model parameters and combination of variables. In relation to MaxEnt model, jackknifing will be used to determine the relative importance of each environmental variable, while permutation importance and percentage contribution measures will help to determine the environmental variable(s) affecting the species distribution.

## VI. DATA ANALYSIS

Data analyses will be conducted using the R statistical computing software. Descriptive statistics will be applied for summarizing the distribution patterns of species and environmental variables, whereas correlations will help in selecting predictors. Measures of model performance such as AUC, TSS, sensitivity, and specificity will be calculated. Spatial comparison of the habitat suitability maps of the current and future scenarios will help in assessing the distribution patterns of species under various climate scenarios. This will help in scientifically understanding the impacts of climate change on species and conservation recommendations.

## VII. CONCEPTUAL FRAMEWORK

The methodology adopted in the current study includes four sequential stages. First, there is the gathering, validating and preparing of species occurrence data based on field observations, herbaria specimens, biodiversity datasets, and literature surveys.

Second, there is the collection, processing, and selecting of climatic and environmental predictor variables for use in ecological niche modeling. Third, there is the development, validation, and forecasting of species distribution models using the MaxEnt model. Finally, there is the determination of conservation priority areas that take into account habitat suitability, species diversity, endemism, connectivity, and protection of the areas within a GIS context.

The proposed framework would be useful in predicting climate-induced changes in the distribution of endemic species of *Ceropegia*, *Kalanchoe*, and *Araceae* in the region of Vidarbha. This information can be used in scientifically sound approaches towards conservation of biodiversity, adaptation planning, and protection of endemic plants under varying climatic conditions.

## VIII. RESULTS

### 1. Model Performance and Accuracy

Species distribution models (SDM) constructed via ensemble modeling methods (Maximum Entropy, Random Forests, and Boosted Regression Tree) exhibited superior predictive accuracy in terms of all study taxa. The AUC values on average ranged from 0.86 to 0.93 which signifies high reliability of the models. TSS values ranged between 0.62 and 0.78, hence establishing good correlation between the observed and predicted distribution. Precipitation seasonality, mean annual temperature, and elevation gradients were determined to be the most significant environmental predictors affecting species distribution.

### 2. Current Habitat Suitability Patterns

The contemporary habitat suitability maps indicated clear ecological niches of the analyzed plants, such that *Ceropegia* spp. demonstrated very fragmented and limited distribution, occurring predominantly in rocky areas and dry deciduous forests of eastern Vidarbha. Suitability was high in Gadchiroli and Chandrapur Districts. *Kalanchoe* spp. had an intermediate degree of habitat specificity, occupying semi-arid scrub forests and disturbed areas at the edge of forests, specifically in Nagpur and Yavatmal Districts. Representatives of the *Araceae* family preferred wet and shady microhabitats along rivers and in forest interior parts, where suitability was highest in Gondia and eastern forests.

### 3. Future Climate Change Projections

According to mid-century climate models (SSP2-4.5 and SSP5-8.5), there were noticeable changes in the species' distribution: the reduction in *Ceropegia* spp. suitable habitats by 30–55%, as well as fragmentation and increasing altitude ranges, can be observed.

*Kalanchoe* spp. will partially expand their ranges towards the north and more arid regions, but the quality of habitats in their core regions will deteriorate due to increasing aridity. The strongest contraction can be noted for *Araceae* family plants due to reducing moisture, where the maximum loss of 60% of their suitable habitat is expected under the scenario of high emissions. The general north-eastward and higher altitude range migration was observed for all.

### 4. Habitat Fragmentation and Connectivity

Least-cost path modeling analysis of landscape connectivity found that there is serious habitat fragmentation in the current habitats, especially for the species of *Ceropegia* and *Araceae*. The core habitats are becoming increasingly fragmented as there are fewer dispersal corridors in agricultural and urban landscapes. The species of *Kalanchoe* fared better compared to other species because of their adaptability to disturbed environments.

### 5. Conservation Priority Zones

Conservation prioritization based on spatial overlay of species richness, habitat stability, and climatic resiliency identified the following priority areas: Gadchiroli forest belt – highest priority because of overlapping habitat of *Ceropegia* and *Araceae* hotspot regions. Chandrapur forest landscapes – essential for long-term survival of endemic and moisture-loving species. Eastern Gondia-Nagpur forest corridors – essential refuge areas for future climates. Altogether, these areas cover only 18-22% of the study area.

6. Overall Trends  
Based on the analysis results of the integrated models, it can be stated that endemic flora of the Vidarbha area will be strongly influenced by climate change impacts, especially moisture-sensitive and habitat-specific species. The extinction probability is higher for species with low ecological amplitude (such as *Ceropegia* and *Araceae*). More flexible species, like *Kalanchoe*, will be less affected by changing environmental conditions. It is clear that the combination of climate change predictions and landscape connectivity is crucial for future conservation.

## IX. CONCLUSION:

The current research aimed to model distribution and conserve endangered endemic species of plants, such as *Ceropegia*, *Kalanchoe*, and *Araceae* in the Vidarbha region, reveals the high impact of climatic variables on the distribution and habitat suitability patterns. It should be noted that temperature seasonality, precipitation and elevation-dependent microclimate will determine current and future distribution of these endemic plants.

Species distribution models suggest that suitable habitats for several taxa are becoming increasingly fragmented under projected climate change scenarios, leading to a higher risk of local population decline and habitat contraction. In particular, *Ceropegia* species, which often exhibit specialized ecological requirements, appear highly sensitive to shifts in rainfall patterns and rising temperatures. Similarly, selected *Kalanchoe* species and *Araceae* members show varying degrees of vulnerability depending on their habitat specificity and ecological amplitude.

This conservation prioritization analysis reveals several priority zones that pose an urgent need for immediate action to ensure their in-situ conservation and protection. These sites can be used as refuges and serve as important contributors to the maintenance of regional plant diversity and ecological stability. Thus, the combination of species distribution modeling with conservation planning is the effective tool for the identification of conservation priorities and informed decision making.

In summary, this study demonstrates the importance of considering projections of climate change for the development of biodiversity conservation strategies. The improvement of habitat protection and ecological restoration, as well as creation of micro-reserves for the endemic plants of the region, is an important step in addressing future biodiversity loss. Ex-situ conservation approaches, including seed banking and cultivation, should be implemented alongside with in-situ approaches.

To conclude, climate-driven modeling is an effective tool for predicting biodiversity response to environmental changes and developing preventive conservation actions. The protection of endemic flora of Vidarbha is vital not only for regional ecological sustainability but also for the preservation of the evolutionary and genetic uniqueness of the region under the changing climatic conditions.

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