



## Original article

A new species of *Emilia* Cass. (Asteraceae) from the Eastern Ghats of India with notes on ecosystem evaluation and conservation statusKoppineedi Veera Satish<sup>a</sup>, Jonnakuti Prakasa Rao<sup>b,\*</sup><sup>a</sup> Forestry and Ecology Group, National Remote Sensing Centre, Balanagar, Hyderabad, Telangana, India<sup>b</sup> Department of Botany, Andhra University, Visakhapatnam, Andhra Pradesh, India

## ARTICLE INFO

## Article history:

Received 17 May 2016

Received in revised form

19 September 2016

Accepted 26 October 2016

Available online 20 January 2017

## Keywords:

Asteraceae

Conservation

Eastern Ghats

*Emilia reddyi*

## ABSTRACT

*Emilia reddyi* is described and illustrated as a new species from the Eastern Ghats of Andhra Pradesh, India. It resembles *Emilia scabra*, *Emilia javanica*, and *Emilia sonchifolia*, but is distinct by the stem which is woody at the base, the strictly cauline leaves, and floral characters. A description, information on habitat, distribution, and phenology, and relevant taxonomic notes are provided. The landscape in which *E. reddyi* occurs was evaluated for the rate of deforestation and land cover changes to understand the anthropogenic impacts on ecosystem of the described species. Based on these data, the conservation status of the species was assessed.

Copyright © 2017, National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA). Production and hosting by Elsevier. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Introduction

*Emilia* Cass. is a taxonomically complex genus (Fosberg 1972; Nicolson 1980) and often perplexing because of its morphological variation. Plants of this genus lose some distinct features when they are dried, which makes a comparative study based on herbarium specimens difficult. However, specialists of *Emilia* have identified the specific taxonomic characters which should be considered in distinguishing taxa (and therefore in describing new species), viz. habit, robustness, leaf shape, texture and margin, pubescence, shape of involucre, relative length of involucre and number and color of florets, length of corolla lobes, and achene surface (Fosberg 1972; Garabedian 1924; Nicolson 1980).

The current number of species has risen to 115 and these are distributed in the tropical and subtropical regions of the world (The Plant List 2015). In India, eight species have been reported, i.e. *Emilia zeylanica* C.B. Clarke, *Emilia alstonii* Fosberg, *Emilia scabra* DC, *Emilia exserta* Fosberg, *Emilia javanica* (Bunn.f.) C. Robinson, *Emilia prenanthoides* DC, *Emilia sonchifolia* (L.) DC, and *Emilia ramulosa* Gamble (BSI 2015). Of these, only two species, *E. scabra* and

*E. sonchifolia* have been reported from the Eastern Ghats (Pullaiah and Moulali 1997; Pullaiah et al 2002; Reddy et al 2008).

During botanical studies in the Eastern Ghats of Araku Valley, Andhra Pradesh, India, we collected specimens of *Emilia* showing distinct vegetative and floral characters. After our critical examination and perusal of literature, these specimens were identified as a new taxon. Moreover, we evaluated long-term changes in the ecosystem to assess the conservation status of a novelty.

## Materials and methods

## Collection of plant material

Field explorations were carried out in the Araku Valley. During this exploration process, specimens of a new taxon were collected on higher elevations of Galikonda during the post monsoon and winter season of 2013 and 2014. In total, six individuals were collected for taxonomic study and to make standard herbarium specimens. Similarly, we collected fresh specimens of *E. scabra* and *E. sonchifolia* from different locations for comparative study. Some of the specimens were fixed with 5% formaldehyde solution for further study. Field and voucher numbers were assigned, and real-time observations on habitat and taxonomic notes were recorded for specimens and deposited in Andhra University Herbarium (AUH), Andhra Pradesh, India.

\* Corresponding author.

E-mail address: [jprakasarao@gmail.com](mailto:jprakasarao@gmail.com) (J.P. Rao).

Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

### Observations of morphological variations in ex situ conditions

We collected a few juvenile individuals to study the morphological variation at lower elevations in the experimental field site in Andhra University. Initially, these individuals were planted in the soil which was collected from the type locality. However, after a few days, we moved them to testing pots with sandy soil, in order to observe morphological variation over their life cycle.

### Satellite data and mapping

Multi-temporal satellite data obtained from Landsat Multi-Spectral Scanner (1973) and Landsat 8 Operational Land Imager (2015) were used for mapping of vegetation types and land cover within the Galikonda hill complex, the type locality. The vegetation types and land cover were delineated on the basis of visual key elements and phenological pattern using Earth Resources Data Analysis Systems Imagine software. Resourcesat-2 Linear Imaging Self Scanning Sensor-III (2014) data were used for reference purpose.

### Rate of deforestation and land cover change

To calculate the annual rate of deforestation and land cover change we used the compound interest formula (Puyravaud 2003):

$$r = \frac{1}{(t_2 - t_1)} \times \ln \frac{a_2}{a_1} \quad (1)$$

where  $r$  is the annual rate of change (percentage per year),  $a_1$  and  $a_2$  are the forest cover and land cover estimates at time  $t_1$  and  $t_2$ , respectively.

### Ecosystem evaluation and conservation status

The spatial extent of land cover changes were assessed for a period of four decades (1973–2015). Classified spatial maps were verified using field data and high-resolution Google Earth (Google Earth 2015) images. The current conservation status of new species was evaluated as per International Union for Conservation of Nature (IUCN) Red List Categories and Criteria Version 3.1

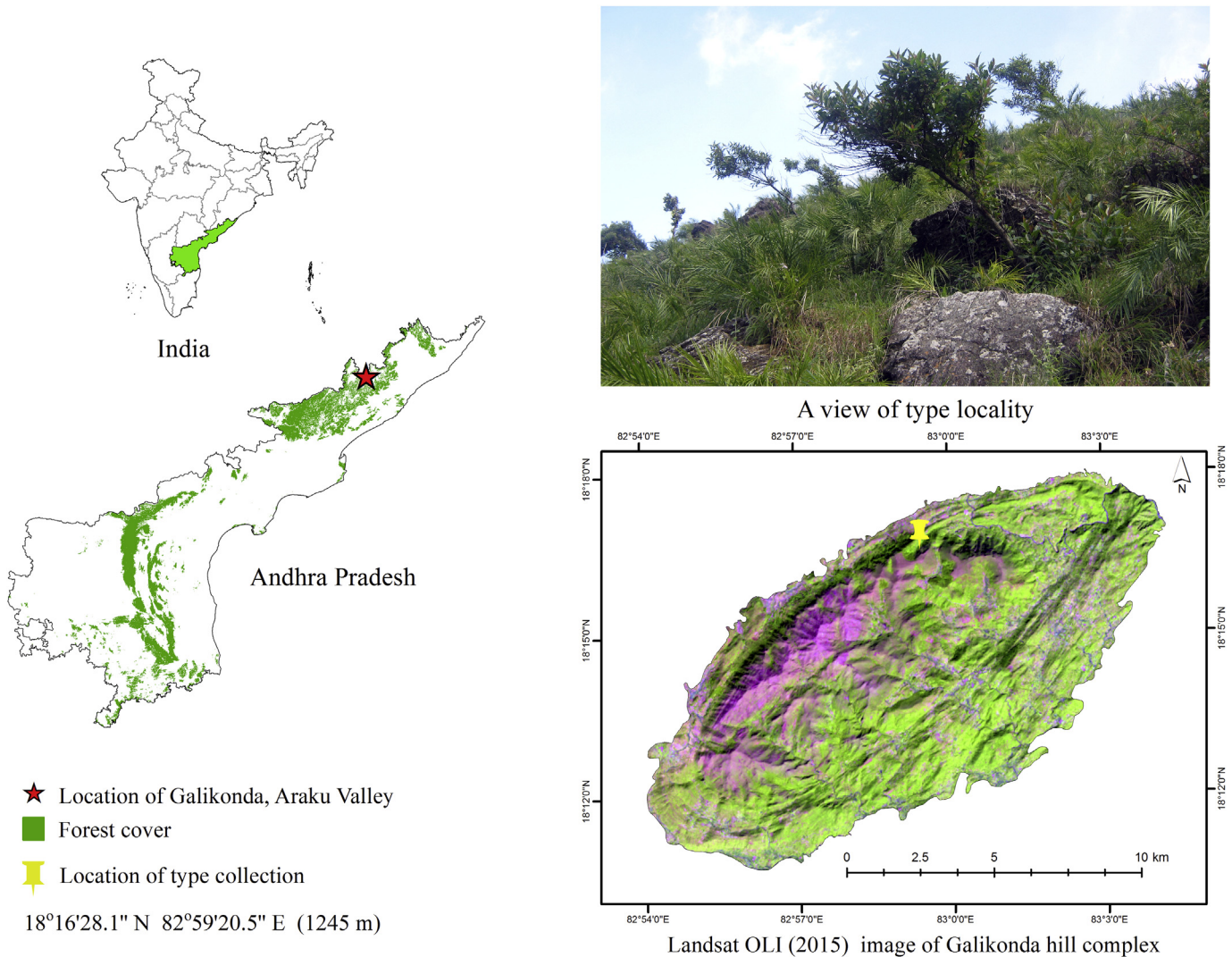
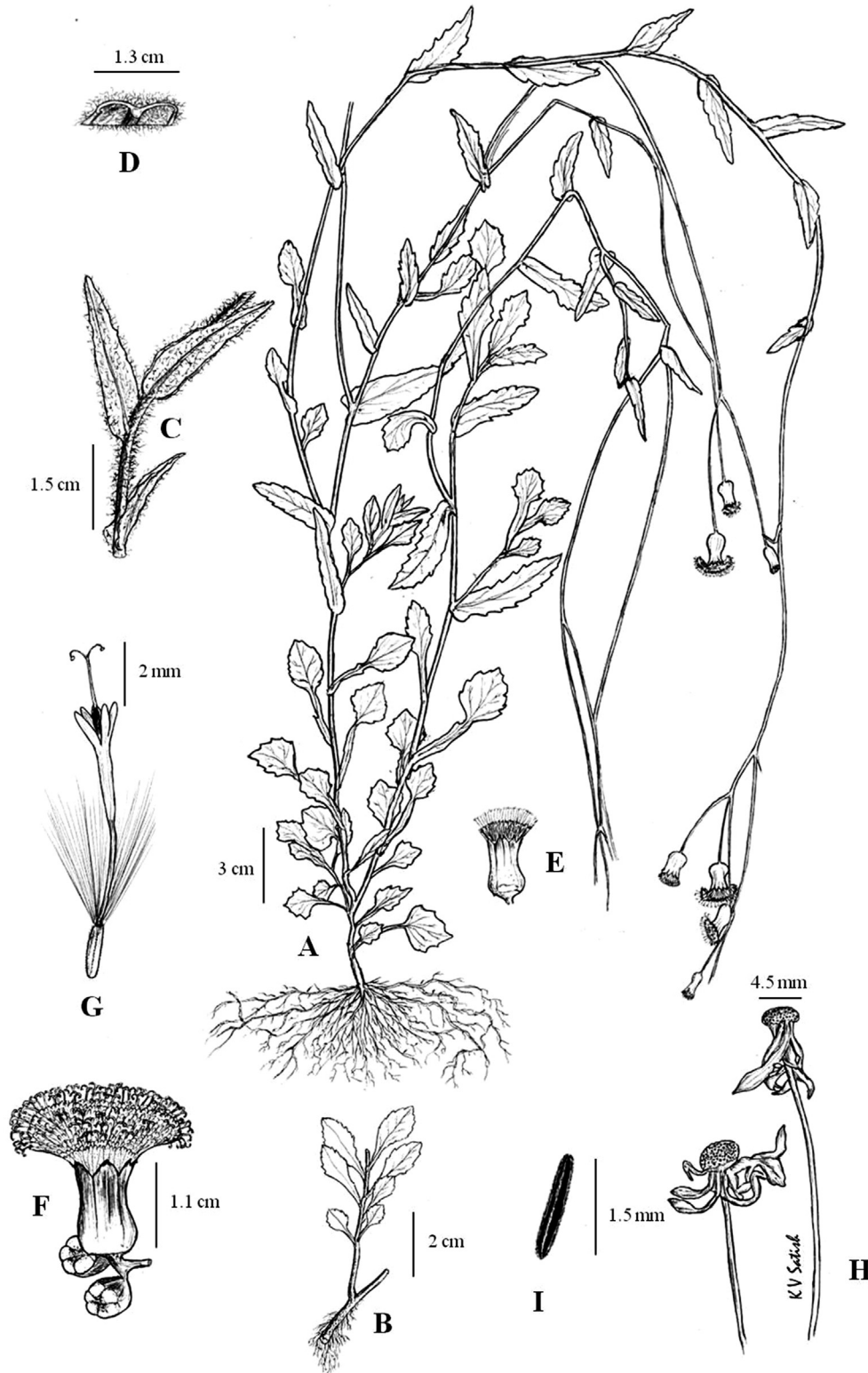


Figure 1. Location map of the type locality of *Emilia reddyi* sp. nov.



**Figure 2.** *Emilia reddyi* sp. nov.: A, *Emilia reddyi* Satish et Praksarao Habit; B, base of the stem showing woodiness; C, densely hairy young branch; D, part of leaf showing hairiness on both sides and recurved margins; E, capitulum at early anthesis; F, flowering head and buds; G, floret; H, upper part of peduncle showing wide receptacle with pits; I, mature achene (pappus removed) showing densely white hispid ribs.



**Figure 3.** *Emilia reddy* sp. nov. A, Habit; B, Twig showing robustness, woodiness at the base and strict cauline leaves; C, Flowering twig; D, Leaf variation in size and shape; E, Lower surface of the leaf showing recurved margin with pigmentation; F, Tender twig with wavy hairs on both stem and leaves.

(IUCN 2015). The extent of occurrence (EOO) and area of occupancy (AOO) was estimated using ArcGIS 10.2.1 software. Output vector was plotted in ArcGIS 10.2.1 software for presentation of classified maps.

#### Site description and plant communities of type locality

The Eastern Ghats are discontinuous hill ranges in peninsular India (Abe et al 2013). However, the forests of the Eastern Ghats are relatively underexplored and have received less attention for conservation compared to the Western Ghats. Due to high elevation and rainfall, the valleys have luxuriant vegetation consisting of semi-evergreen, moist deciduous, and dry deciduous forests. In the Eastern Ghats, Araku valley is one of the ecologically sensitive and biologically rich areas (Rao et al 2015) with strict global endemics including *Argyrea arakuensis*, *Phyllanthus narayanswamii*, *Argyrea srinivasanii*, *Bupleurum andhricum*, *Kalanchoe cherukondensis*, *Leucas mukherjiana*, and *Ophiorrhiza chandrasekharanii* (SubbaRao and Kumari 2002). Araku Valley comprises the Anantagiri and Sunkarimetta Reserved Forest. It is located between 82°51'40" and 83°06'53" of E longitude and 18°12'34" and 18°25'12" of N latitude (see Figure 1). Altitude ranges from 800 m to 1520 m. This valley consists of a continuous hill system with Galikonda, Raktakonda, Sunkarimetta, and Chitamogondi complex, of which Galikonda rises to a height of 1510 m. The average annual precipitation is 1700 mm, the bulk of which is received during June to October (Pattanaik et al 2009). *Phoenix* savannah is one of the predominant vegetation covers of hilltops dominated by *Phoenix loureirii*. Hills which are surrounded by Galikonda and Raktakonda are comparatively dry and thus support scrub vegetation. The new taxon occurs on open hill slopes of *Phoenix* savannah at an altitude of about 1245 m, associated with *P. loureirii*, *Anaphalis adnata*, *Crotalaria mysorensis*, *Swertia angustifolia*, *Hypericum gaitii*, *Osbeckia stellata*, *Phyllanthus emblica*, *P. narayanswamii*, *E. sonchifolia*, *Scutellaria*

*violacea*, *Chrysopogon aciculatus*, *L. mukherjiana*, *Rubia cordifolia*, *Indigofera cassioides*, *Bidens pilosa*, *Chromolaena odorata*, *Gynura lycopersifolia*, *Rubus ellipticus*, and *Rubus niveus*.

## Results and discussion

### Taxonomic accounts

#### *Emilia reddy* Satish et Prakasarao, sp. nov.

**Type.** India. Andhra Pradesh, Visakhapatnam, Araku Valley, Galikonda hilltop, 500 m away from Galikonda viewpoint, 1245 m alt, 18°16'28.1" N, 82°59'20.5" E, 07 Dec 2013, K.V. Satish, J. Prakasa Rao 21202 (CAL, Holotype.; AUH, DRC, MH, BSJO, Isotypes).

**Diagnosis.** Robust annual herb, grows up to 85 cm long. Leaves strictly cauline, margin wavy, dentate, recurved. Mature involucre glossy, strictly glabrous, about three-quarters the corolla length. Involucre base urceolate to globose. Receptacle 4.5 mm wide; florets 60–75 per head, much exserted. Corolla lobes linear to broadly oblong, apex obtuse. Style 7.5 mm long, exserted from corolla up to 2 mm, style arms short, recurved, stigma capitate. Achenes up to 2.75 mm long, distinctly white hispid on ridges. Seeds black.

**Description.** Robust, annual herb, grows up to 85 cm height. Stem erect, woody at the base, terete, 0.5–3 mm diameter, branched, densely pilose when young, sparsely pilose when mature, round, green gradually turning to deep purple, internodes up to 8 cm long. Leaves strictly cauline, alternate, simple, sessile, 1–5.5 cm × 0.5–2 cm, variable in shape and size, the basal leaves spatulate, lyrate, middle leaves linear-oblong, apex subobtuse, upper leaves sagittate, apex acute, margins undulate, dentate, recurved, pigmented with deep purple color; glossy on adaxial side, leaf base auriculate, lobed, upper leaves somewhat clasping at the base, sparsely pilose on both sides with wavy hairs of unequal height. Peduncle up to 23 cm long, solitary or branched, with 1–4 homogamous heads. Capitulum base urceolate to globose, somewhat thickened, glossy.



Figure 4. Holotype of *Emilia reddyi* sp. nov.

Involucre about three-quarters the corolla length. Involucral bracts nine, lanceolate, 9–11 mm long, green, sometimes turning rosy brown, margins purple, sparsely pilose when young, glossy and glabrous when mature. Heads up to 1.4 cm length, with up to 75 florets per each head, florets much exserted. Receptacle somewhat pitted, width up to 4.5 mm. Pappus finely barbellate, white, 9 mm long. Corolla color violet plum, tubular, 5.5–7.5 mm long, 0.1 mm wide, lobes linear to broadly oblong, 1–1.5 mm × 0.5 mm, apex

obtuse. Stamens 7 mm long, exserted about 3–4 mm from corolla, somewhat transparent, 0.1 mm long, apical appendage linear, <0.1 mm long, apex acute; pollen grains round, surface spiny, yellow. Ovary 1.5 mm long, style 7.5 mm long, exserted from corolla up to 2 mm and forming a crown-like structure, pale purple, stigma lobes 0.1 mm long, capitate, pigmented with dark pink to violet color. Achene 2.5–2.75 mm long, angled, 5-ribbed, not deeply ribbed, densely white hairy on ridges. Mature seeds black.

**Flowering period.** September to February (Figures 2–4).

**Etymology.** The specific epithet of species was given in honor of Dr. C. Sudhakar Reddy, Scientist, National Remote Sensing Centre, Indian Space Research Organisation, Hyderabad, India for his significant contributions in plant taxonomy and biodiversity of India.

#### Recognition of new taxon and key to close relatives

This taxon differs from all other known species of *Emilia*, however, it has affinities with *E. scabra*, *E. javanica*, and *E. sonchifolia*. Hence, we have collected respective related species and critically evaluated these taxonomically, which showed this species would key out near to *E. scabra*, *E. javanica*, and *E. sonchifolia* but differs in the habit, robustness with strict cauline glossy leaves, involucre glossy and glabrous, florets exerted from the involucre, style exerted up to 2 mm outside, capitate stigma. Comprehensive comparative and individual information is provided in Table 1.

#### Observations of morphological variations in ex situ conditions

After critical observation in the experimental field site, it was found that there was a drastic change in leaf morphology, which became pale green in color, very thin, and lost their glossiness and dense hairiness on the leaf as well as the stem. Leaves remained strictly cauline but showed the dominance of lyrate shaped leaves

even at the top portion of the stem. Stem remained dark purple pigmented but lost woodiness at the base, whereas floral parts did not show variation except the color of involucre bracts, which became rosy brown to pale green in color. However, the special characters, including much-exserted florets and style, receptacle wideness, the number of florets, and corolla lobe length, still remained the same with no variation. With reference to seed setting, we did not find even a single mature achene; this may be because of missing natural pollinators in the tested site or physiological changes in the plant.

#### Ecosystem status

In the present study, we used the satellite remote sensing data to map and monitor the long-term ecosystem change over the past four decades (1973–2015). The result of habitat evaluation showed that natural vegetation occupies an area of 91.7 km<sup>2</sup> (65.0%) of the total study area. Amongst the natural vegetation, *Phoenix* savannah (*P. loureirii* gregarious) is the predominant land cover which occupies an area of 26.1 km<sup>2</sup> (18.5%), followed by scrub (24.0 km<sup>2</sup>/17.0%), semi-evergreen forest (22.4 km<sup>2</sup>/15.8%), moist deciduous forest (15.5 km<sup>2</sup>/11.0%), and dry deciduous forest (3.7 km<sup>2</sup>/2.6%). The total area under *Phoenix* savannah has been considered as the EOO of *E. reddyi* (Figure 5). The AOO occurs within a patch of *Phoenix* savannah. Distribution of forest vegetation and other classes are shown in Table 2.

**Table 1.** Comparative morphology of *Emilia reddyi* with its close relatives.

Sl. no	Characteristics	<i>Emilia sonchifolia</i> (L.) DC.	<i>Emilia javanica</i> (Burm.f.) C. Robinson	<i>Emilia scabra</i> DC.	<i>Emilia reddyi</i> sp. nov
I	Vegetative characters				
1	Habitat	Fields & wastelands	Wastelands	High-altitude grasslands	Hilltop savannah
2	Habit	Annual, weak herb (up to 90 cm long)	Annual, stout herb (up to 60 cm long)	Annual, weak herb (up to 20 cm long)	Annual, robust herb (up to 82 cm long)
3	Stem	Not woody at the base	Shrubby	Not woody at the base	Woody at the base
4	Leaves	Radical, mostly cauline, upper leaves sagittate	Mostly cauline, upper leaves not sagittate	Radical very few cauline, upper leaves sagittate	Strictly cauline, upper leaves sagittate
5	Mature leaf condition	Moderately thick	Moderately thick	Thick	Relatively thin
6	Leaf base	Base obtusely auriculate	Base obtusely auriculate	Base acutely auriculate	Base obtusely auriculate & slightly clasping
7	Leaf margin	Sinuate-serrate	Entire to distantly serrate, not recurved	Slightly wavy recurved, crenate	Slightly wavy recurved, dentate
8	Leaf surface	Glabrescent to pubescent	Glabrous to crisped-pubescent	Crisped-pubescent	Glossy & sparsely pilose
II	Reproductive characters				
9	Capitulum base	Narrowly cylindrical, not thickened	Campanulate, thickened	Cylindrical, not thickened	Urceolate to globose, somewhat thickened
10	Phyllaries surface	Sparsely pilose to glabrous	Glabrous	Hairy all time	Glossy glabrous when mature
11	Relative length of involucre	Almost equaling the corolla length	Half of the corolla length	About three-quarters the corolla length	About three-quarters the corolla length
12	Capitulum length	1–1.2 cm	1–1.2 cm	1–1.2 cm	1–1.4 cm
13	Involucral bracts, color	7–10 (6–12 mm long), green to pale green	12–14 (6–8 mm long), green to pale green	8 (7.6 mm long), green to brownish green	9 (9 mm long), green to rosy brown
14	Diameter of receptacle	Convex, 2–7 mm	Convex, up to 7 mm	Convex, 2.1 mm	Convex, 4.5 mm
15	Floret number	35–60	Up to 90	35–45	60–75
16	Corolla length	5.5–10 mm	9–11 mm	7–7.5 mm	5.5–7.5 mm
17	Corolla lobe length	0.6–1.5 mm	2.5 mm	0.5–0.75 mm	1–1.5 mm
18	Corolla color, lobe shape	Pink or purplish, broadly triangle	Reddish magenta, lanceolate	Lilac, elliptical	Violet plum, broadly oblong
19	Corolla lobe apex	Acute	Acute	Apiculate	Obtuse
20	Style exerted	Scarcely exerted	Scarcely exerted	Scarcely exerted	Exserted from corolla up to 2 mm outside & forms crown like structure
21	Style arms	Short with acute stigma	Long with conical stigma	Truncate with minute stigma	Short, recurved, capitate stigma
22	Hairy on ridges of achene	Sparsely visible to clearly so	Distinctly visible	Sparsely visible	Distinctly visible
23	Mature seeds	2.5–3 mm long, rustic copper color or red-brown	2–3 mm long, pale brown	2.5–2.75 mm long, rustic copper to brown	2.5–2.75 mm long, black

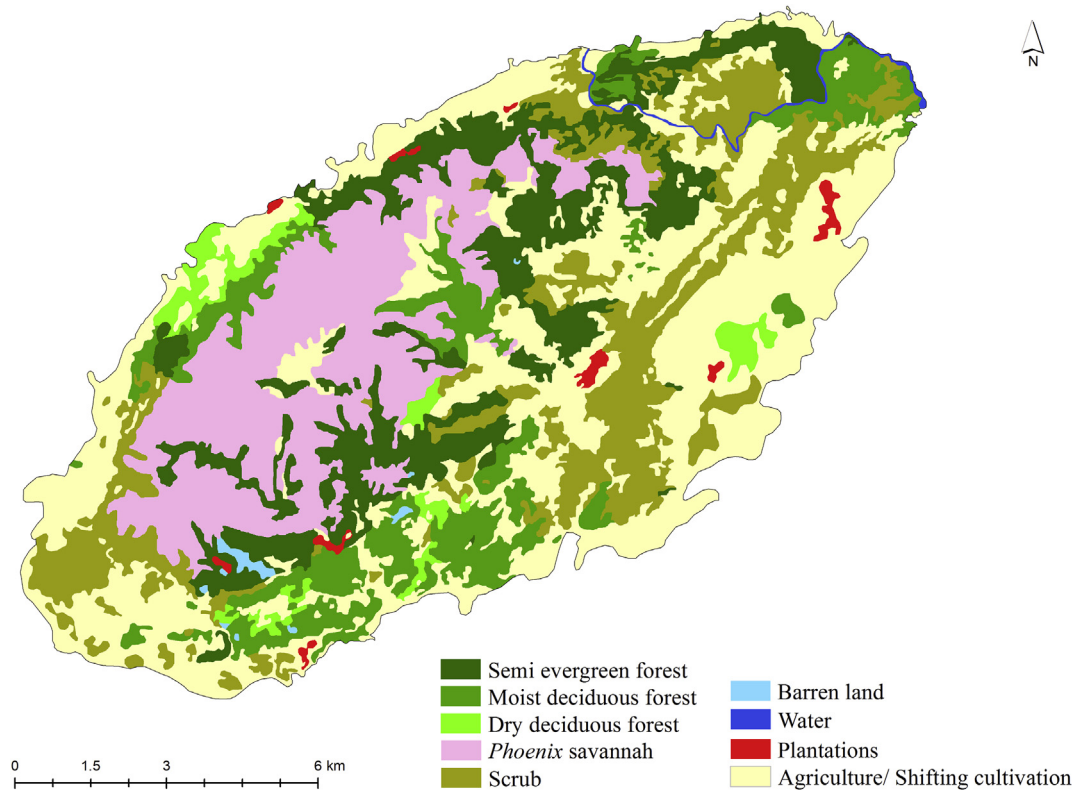


Figure 5. Forest types and land cover map of Galikonda hill complex ecosystem.

Long-term ecosystem change assessment (1973–2015)

Understanding the long-term effect of anthropogenically induced changes in the ecosystem is essential for effective conservation of native biodiversity. In the present study, it was observed that the habitat of *E. reddyi* is under extreme pressure due to massive forest cover change and other anthropogenic impacts. The primary cause of deforestation is due to the expansion of agriculture considerably up to an area of 11.0 km<sup>2</sup> (25.9–33.6%). Total forest loss was estimated at 9.1 km<sup>2</sup> which was 18.0% of the total forest area. Semi-evergreen forest lost an area of 5.4 km<sup>2</sup> (19.4%), followed by moist deciduous, dry deciduous, *Phoenix* savannah, and scrub with loss of 3.1 km<sup>2</sup> (16.9%), 2.6 km<sup>2</sup> (14.0%), 0.2 km<sup>2</sup> (0.6%), and 1.9 km<sup>2</sup> (7.4%), respectively. The areal extent of land cover and change is shown in Table 2, and Figures 6 and 7.

Table 2. Area statistics of forest types and land cover and its four decadal changes (area in km<sup>2</sup>).

Sl. no	Class	1973	% of area	2015	% of area	Change	Rate of change*
1	Semi evergreen forest (SE)	27.7	19.7	22.4	15.8	-5.4	<b>0.51</b>
2	Moist deciduous forest (MD)	18.6	13.2	15.5	11.0	-3.1	<b>0.44</b>
3	Dry deciduous forest (DD)	4.3	3.1	3.7	2.6	-0.6	<b>0.36</b>
4	<i>Phoenix</i> savannah (PS)	26.3	18.6	26.1	18.5	-0.2	<b>0.01</b>
5	Scrub (S)	25.9	18.4	24.0	17.0	-1.9	<b>0.18</b>
6	Barren land (B)	0.4	0.3	0.4	0.3	0.1	0.55
7	Plantations (O)	0.9	0.6	1.01	0.7	0.1	0.31
8	Agriculture/Shifting cultivation (A/SC)	36.5	25.9	47.5	33.6	11.0	0.62
9	Water (W)	0.5	0.4	0.5	0.4	0.0	0.00
		141.2	100	141.2	100		

\* Negative changes in classes are shown in bold italics.

Rate of deforestation and land cover change

Significant rate of deforestation and land cover changes were observed in the present study. The semi-evergreen forest underwent deforestation with 0.51% annual rate of loss, followed by moist deciduous and dry deciduous with 0.44% and 0.36% respectively. The scrub showed 0.18% annual loss. Agriculture has drastically extended with an annual rate of 0.62%. Barren land and orchards extended 0.55% and 0.31% respectively. The analysis proved that there is a strong footprint of anthropogenic threats (Table 2).

Conservation status

Based on intensive field observations, *E. reddyi* has only one population with roughly 70 individuals across the AOO of 0.22 km<sup>2</sup> (22.6 ha) and the EOO of 26.1 km<sup>2</sup> (2612.1 ha); both values are below the threshold for critically endangered. The EOO and AOO

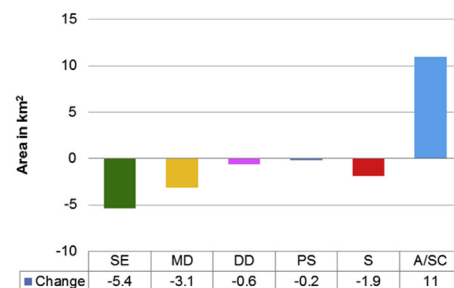


Figure 6. Major changes in forest types and land cover of study area (1973–2015).

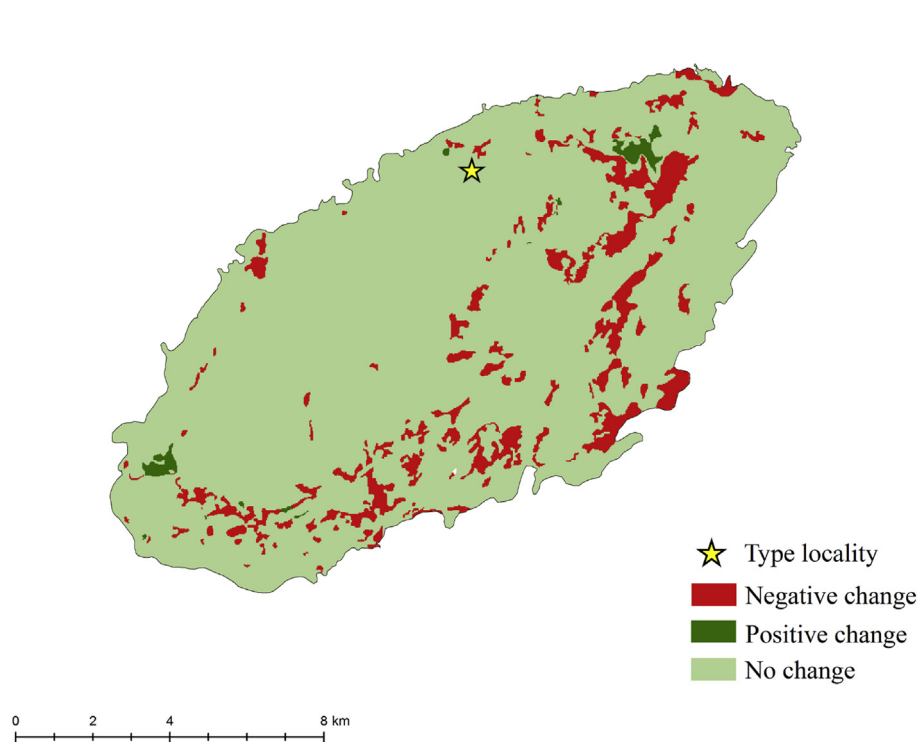


Figure 7. Vegetation changes from 1973 to 2015.

were calculated using a classified map of 2015 and digitizing the respective polygons using ArcGIS software. The species is only known in the transition slopes of *P. loureirii* savannah and semi-evergreen forests of the Galikonda hilltops. During summer, the habitat is frequently affected by fires. The spread of invasive alien species (*Ageratina adenophora*, *B. pilosa*, and *C. odorata*), intense grazing pressure, pepper and coffee plantation, and adjoining land cover changes due to agricultural expansion and tourism pressure, thus the type habitat is shrinking. The hilltop savannah of Galikonda and Raktakonda has been proposed for bauxite mining activities by Andhra Pradesh Mineral Development Corporation Limited (GSI 1994; Pattanaik et al 2009) which can be a major threat to the continued existence of the new taxon. Applying the IUCN Red List Categories and Criteria Version 3.1 (IUCN 2015), we assessed this taxon as critically endangered CR B1 a + B2 a.

#### Conflict of interest

No conflict of interest was reported by the authors.

#### Acknowledgments

The authors are thankful to Dr. V. K. Dadhwal, Former Director, NRSC, Dr. P. G. Diwakar, Scientific Secretary, ISRO, Dr. C. S. Jha, Group Director, Forestry and Ecology Group, NRSC, Professor M. Venkaiah, Professor O. Aniel Kumar, Professor Y. V. Rao, Dr. S. B. Padal, Department of Botany, Professor P. V. V. Prasada Rao, Professor P. S. Raja Sekhar and Professor A. J. Solomon Raju, Department of Environmental Sciences, Andhra University, Dr. B. Venkateshwara Rao, Department of Botany, Government College (A), Rajahmundry, and Dr. M. Suryanarayana Raju, Department of Botany, Government College, Razole, Andhra Pradesh for support and encouragement. Authors are grateful to barefoot botanists for their help during the

field studies. Thanks are due to the editor and anonymous reviewers for suggestions and critical comments.

#### References

- Abe R, Sekhar CR, Sasaki S, Shivananda K, Shinji M. 2013. Eastern Ghats biodiversity reserves with unexplored lichen wealth. *Current Science* 104:821.
- BSI (Botanical Survey of India). 2015. *e-flora of India*, Ministry of Environment and Forest & Climate Change, Government of India. Available at: <http://efloraindia.nic.in/efloraindia/taxonList.action?id=5590&type=4> [Date accessed: 16 March 2016].
- Fosberg FR. 1972. *Emilia* (Compositae) in Ceylon. *Ceylon Journal of Science (Biological Sciences)* 10:61–69.
- Garabedian S. 1924. A revision of *Emilia*. *Bulletin of Miscellaneous Information (Royal Gardens, Kew)* 1924:137–144.
- GSI (Geological Survey of India). 1994. *Detailed information on Bauxite in India*. Available at: [http://www.portal.gsi.gov.in/gsiDoc/pub/DID\\_Bauxite\\_WM.pdf](http://www.portal.gsi.gov.in/gsiDoc/pub/DID_Bauxite_WM.pdf) [Date accessed 07 December 2015].
- Google Earth. 2015. Available at: <https://www.google.com/earth/download/ge/agree.html> [Date accessed 02 November 2015].
- IUCN (International Union for Conservation of Nature). 2015. *The IUCN red list of threatened species, version 3.1*. Cambridge U.K.: IUCN Red List Unit. Available at: <http://www.iucnredlist.org/> [Date accessed 20 November 2015].
- Nicolson DH. 1980. Summary of cytological information on *Emilia* and the taxonomy of four Pacific taxa of *Emilia* (Asteraceae: Senecioneae). *Systematic Botany*; 1980:391–407.
- Pattanaik C, Prasad SN, Reddy CS. 2009. Need for urgent conservation of biodiversity in Araku Valley, Andhra Pradesh. *Current Science* 96:11–12.
- Pullaiah T, Moulali DA. 1997. *Flora of Andhra Pradesh*, vol. II. Jodhpur, India: Scientific Publishers.
- Pullaiah T, Rao DM, Ramamurthy KS. 2002. *Flora of Eastern Ghats: Hill ranges of South East India*, vol. II. New Delhi: Daya Books.
- Puyravaud JP. 2003. Standardizing the calculation of the annual rate of deforestation. *Forest Ecology and Management* 177:593–596.
- Rao JP, Satish KV, Sankar BS, et al. 2015. On the occurrence of parasitic plant *Balanophora fungosa* JR Forster & G. Forster (Balanophoraceae) in Andhra Pradesh, India. *Journal of Threatened Taxa* 7:6943–6946.
- Reddy CS, Reddy KN, Raju VS. 2008. *Supplement to Flora of Andhra Pradesh, India*. New Delhi: Deep Publications.
- SubbaRao GV, Kumari GR. 2002. *Flora of Visakhapatnam district, Andhra Pradesh*. Kolkata: Botanical Survey of India.
- The Plant List. 2015. *The Plant List a working list of all plant species*. Available at: <http://www.theplantlist.org/> [Date assessed 21 November 2015].