Digital Floristic Reconnaissance of Understorey and Associated Vegetation in a Sal-Dominated Forest Landscape of Dehradun, Uttarakhand, India

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Abstract
The understorey vegetation makes a significant portion of biodiversity in the forest though it is typically hidden and less documented when compared to the tree layer. This research delivers the first digital study of flora in trees of an area close to Dehradun, Uttarakhand, India based on the student field mission which made use of digital photographs, georeferenced images and iNaturalist identification. The study has compiled 26 species representing 19 families of plants whereby Lamiaceae contributed four entries whereas two records each were made for Poaceae, Asteraceae, Euphorbiaceae and Apocynaceae. The species belong to herbaceous plants, shrubs and grasses, a fern and a perennial vine. The geographical coordinates were taken from GPS images in the photographs and show the location of all 26 plant entries. The research did not estimate the species richness or community diversity due to lack of quadrat or transect data; however, it illustrates that the method of photo-based biodiversity documentation can assist in making initial preliminary studies in the field. The results further reiterate that any automated or community-assisted identification should be verified independently prior to making species-level floristic claims in ecological analysis. The data set serves as a useful base for future quantitative investigations which investigate understory composition in relation to canopy openness, disturbance, soil characteristics, and seasonality.

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1. Introduction

Forest biodiversity refers not only to the principal trees but also to the flora that grows in the understorey, ground level, gaps and on the edges of the forest. Some understorey plants affect nutrient cycling, regeneration of the forest, soil conservation, habitat formation and functioning of ecosystems. Moreover, the assemblage of understorey plants can react quickly to the changes of light, moisture and forest cover structure (Landuyt *et al*., 2019; Deng *et al*., 2023) [5, 7]. Thus, in the Sal system, the study of herbs, shrubs, grasses, vines and ferns can be effective in complementing traditional forest inventories.

Understorey vegetation is important in the ecology of the forest but it is not always easy to study due to the small sizes one should master to mention this flora. Traditional methods of floristic inventories are necessary, however, new methods of collecting data like photography and bio platforms make the process quicker and easier thanks to connecting the observation of an organism with visual proof that is time and location marked. The success of such projects as the one based on iNaturalist illustrates that observation-based technique becomes crucial for biodiversity studies (Di Cecco *et al*. 2021; Mason *et al*. 2025) [4, 8].

It has been noted that the interaction between observers, automated identification and the community of identifiers is instrumental in making such platforms as iNaturalist effective. The research has shown that though the contribution of identifiers is invaluable in making the observations research-ready, the identification quality differs, depending on the type of taxa, quality of the images and the experience of the identifier (Callaghan *et al*., 2022; Campbell *et al*., 2023) [2, 3]. Thus, digital records can be useful if treated as documented observations rather than as automatically confirmed species identifications.

As for forestry education, the advantage of this workflow consists in disposing of a double function. Namely, during the field exercise, it allows students to observe some morphological characteristics of the plants, register relevant geographic data, take necessary photos and use the digital identification tools, as well as to understand the difference between an observation and the identification.

This work continues the student's previous studies on the vegetation documentation in the form of a preliminary floristic research article. The goals of the work include: (i) to collect and process the plant observations made earlier; (ii) to provide the description of the families and forms of plants; (iii) to report the ecological and ethnobotanical facts that were apparent in the process of the work; (iv) to keep the georeferencing of the photos; (v) to analyze the possibilities and limits of using digital documentation workflow as a starting point for future measurements of understory.

2. Methodology

2.1. Study location

The fieldwork was undertaken in a subtropical forest environment at Manduwala, located near Dehradun, Uttarakhand, India. The area has characterized by a humid subtropical climate, which means that summers are moderate, winters are relatively cool, and monsoon rains occur between June and September. The vegetation is mainly represented by *Shorea robusta* (also called Sal) and the presence of associates makes it resemble a tropical moist deciduous forest. All these pieces of information have been preserved to illustrate the study area in the field report instead of presenting it as an independent classification of vegetation or climate.

It is important to talk about the ecological context as the recent studies on Sal forests in the Central Himalaya have shown that the composition of the vegetation varies depending on management conditions, and herbaceous and shrub layers are significantly contributing to the differences in floristic structure (Joshi & Joshi, 2025) [5]. In other words, the present data cannot be compared quantitatively with the studies since they do not include standardized sampling procedure.

2.2. Field study and photographic evidence

Field studies were conducted during the morning hours because this was the time when the students reported that the illumination was acceptable for plant photographs. Different plants were photographed in the field and the observations were georeferenced according to the iNaturalist method. The observation table consists of taxon name, habit, family, visible field characteristics, a note on ecology or medicine, and a photo accompanying each observation. These entries are used as the main source of the data for the study reported in the article (see Table 1). Photographs as documentary data were used, rather than replaced by identification specimens. This is important, since in case flowers, fruits, reproductive parts, or other identifying features were absent or difficult to identify. When digital photographs are used, however, this allows the visual data to be verified (Campbell *et al*., 2023; Mesaglio *et al*., 2025) [2, 9].

2.3. Digital identification and taxonomic treatment

The digital identification process began with an image recognition process based on iNaturalist's services, enabling students to observe community validation. This process aligns with iNaturalist's mission to provide an identification tool that utilizes human verification of automated outcomes (Callaghan *et al*., 2022; Campbell *et al*., 2023) [2, 3]. In the current manuscript, the names in the original field report are treated as working identifications and shall not be considered fully verified taxonomic determinations. For the purposes of journal submission, the species identifications should be verified in specialist taxonomic sources such as Plants of the World Online where individual species level identification is confirmed by a factual identification of the floras in the range of the species.

2.4. Georeferencing and spatial data

Coordinates were taken from the GPS photo overlays shown in the field photos. Therefore, the coordinates are those of GPS photos and not iNaturalist data. We were able to use the 26 field photos to create a full set of coordinates (Table 2) because there are coordinates with sufficient accuracy in every photo. The coordinates were given with six digits after zero, because this is the accuracy of the data obtained from the photos and this is only indicative of how well the coordinates were obtained.

2.5. Data organization and analysis

The collection of plant records composed of 26 observations from the original observation table was analyzed. The family of plants including the forms of plants was summarized using nominal frequencies. There was no community analysis based on abundances, because the sources do not provide fixed sampling units, sampling length, or any other measurements that would enable measuring abundance, density or any other aspects of appearance. Therefore, Shannon-Wiener, Simpson index for diversity and other indicators were not calculated. The photographic plate resulting from field observations was created visually synthesizing the documented flora (Figure 2). The plate is limited to providing labels in alphabetical order and no other text that could potentially complicate the images presented.

3. Results

3.1 Botanical evidence and representation within the families

A total of 26 plants were collected based on the assessment results, in which 19 botanical families were represented. The most dominant family was Lamiaceae, with 4 taxa represented. Families Poaceae, Asteraceae, Euphorbiaceae and Apocynaceae contributed 2 representatives each while the other families had only one representative. The flora that has been identified is diverse within families which indicates that there is enough representation of plant taxa. The dataset comprising taxon names, form, families, structures and other ecological or medicinal notes is given in Table 1. The family composition gives useful information at reconnaissance level because these records include taxa that belong to herbaceous, bushy, grassy, climbing and fern forms of life. However, plant families' count should not be perceived as an index of their dominating forms in forests because their records were not obtained via equal area or probabilistic sampling methods.

Table 1: Plant records documented during the exploratory field survey

No.	Taxon (working identification)	Habit	Family	Key field feature	Ecological/medicinal note reported
1	*Flemingia strobilifera*	Shrub	Fabaceae	Compound leaves and clustered flowers	Nitrogen fixing ability
2	*Thysanolaena latifolia*	Herb	Poaceae	Green flowers; bloom in late summer and mature brown	Promotes soil conservation on slopes
3	*Galium aparine*	Herb	Rubiaceae	Flowers white, tinged with green	Associated with fertile, nutrient-rich soils
4	*Youngia japonica*	Herb	Asteraceae	Branched inflorescences with small yellow flowers	Reported as a weed in agricultural, landscape and natural settings
5	*Ziziphus mauritiana*	Shrub	Rhamnaceae	Petiolate, glabrous leaves	Fruit-bearing; medicinal use reported
6	*Colocasia esculenta*	Herb	Araceae	Tuberous leaves	Medicinal properties reported in source
7	*Euphorbia neriifolia*	Shrub	Euphorbiaceae	Leathery leaves	Antibacterial properties reported
8	*Colebrookea oppositifolia*	Shrub	Lamiaceae	Panicles of upright spikes	Traditional medicinal uses reported
9	*Ricinus communis*	Shrub	Euphorbiaceae	Yellowish-green flowers and spiny seed capsules	Toxicity noted
10	*Pogostemon benghalensis*	Shrub	Lamiaceae	Aromatic plant	Medicinal/agricultural uses reported
11	*Calotropis gigantea*	Shrub	Apocynaceae	Milky stem	Reported as a road-edge colonizer
12	*Anisomeles indica*	Herb	Lamiaceae	Densely appressed white pubescence	Carminative, astringent and tonic uses reported
13	*Clerodendrum infortunatum*	Shrub	Lamiaceae	White flowers with pink centre in branched clusters	Traditional medicinal use reported
14	*Solanum violaceum*	Shrub	Solanaceae	Shiny orange berries	Reported from seasonally dry tropical conditions
15	*Lepidagathis incurva*	Herb	Acanthaceae	Hispid, nerved leaves	Native range note reported in source
16	*Pteris vittata*	Herb	Pteridaceae	Sori/spores forming lines along pinna margins	Herbaceous fern
17	*Acmella paniculata*	Herb	Asteraceae	Yellowish-brown capitula	Traditional toothache use reported
18	*Hydrocotyle umbellata*	Herb	Araliaceae	Small vascular plant with peltate/rounded foliage	Habitat note reported in source
19	*Androsace umbellata*	Herb	Primulaceae	Flowers arranged in terminal umbels	Traditional medicinal uses reported
20	*Mazus pumilus*	Herb	Mazaceae	Purple-white flowers with yellow throat markings	Occurs in cultivated/open disturbed microsites
21	*Dioscorea oppositifolia*	Perennial climbing vine	Dioscoreaceae	Unisexual flowers in axillary spicate/paniculate inflorescences	Medicinal and economic value reported
22	*Oplismenus sp.*	Herb	Poaceae	Green lanceolate to ovate leaves with wavy margins	Rapid spread/dense mats noted
23	*Jasminum officinale*	Climber or shrub	Oleaceae	Pinnate leaves and white starry flowers	Ornamental/fragrant value reported
24	*Carissa carandas*	Shrub	Apocynaceae	Opposite ovate-oblong leaves; fragrant white flowers	Nutritional and pharmacological significance reported
25	*Oxalis corniculata*	Herb	Oxalidaceae	Yellow five-petalled flowers	Widely adaptable; common in open/agricultural sites
26	*Triumfetta rhomboidea*	Shrub	Malvaceae	Distinctive rhomboid leaves	Folk medicinal use and fibre value reported

The table reproduces field observations while standardizing obvious formatting (e.g., spelling and family display). Ecological and medicinal notes are presented as reported observations/uses and are not treated as site-specific experimental findings.

3.2. Representation of Growth Forms

In the original observation table, there were 12 records of shrubs (see Table 1) ; 13 records of herbs and 1 record of Perennial climbing vine. Subcategories include perennial climbing vine, grass, climber or shrub, and weed. As such, the derived data reflect vegetation diversity exceeding simple herb–shrub recognition and thus facilitates the assessment of vegetation because different growth forms occupy different niches in horizontal and vertical directions, and react differently to disturbance, moisture, and light availability. At the same time, the mentioned growth forms may not be strictly defined. For instance, 'weed' is not a botanical term but rather an ecological or a management term while 'climber or shrub' means both growth types. Thus, the growth forms mentioned are kept as field report forms but not translated into life form spectrum.

3.3. Ecological and ethnobotanical observations

The field notes connected to the observations give one aspect of information apart from taxonomic identity. *Flemingia strobilifera* was shown to have the characteristics of nitrogen-fixing while *Thysanolaena latifolia* was said to help in soil preservation on slopes. Some observations are accompanied by a note regarding their medicinal use, food, fiber and ornamental use as in case of *Ziziphus mauritiana*, *Colocasia esculenta*, *Pogostemon benghalensis*, *Anisomeles indica*, *Clerodendrum infortunatum*, *Acmella paniculata*, *Dioscorea oppositifolia* and *Carissa carandas*. There are some observations that show the possibility of the existence of plants which can grow in disturbed or open microsites. *Youngia japonica* is said to grow in agricultural sites, landscape settings and natural environments, *Calotropis gigantea* was mentioned as a plant growing along roadsides, *Mazus pumilus* was said to grow both in cultivated area and waste grounds, *and Oxalis corniculata* was said to have its presence in gardens, landscapes and agricultural fields (table 1). All of these observations indicate that plants from forest edges, gaps and disturbed microhabitats have substantial ecological role, but the information is based on hypotheses, not precise data.

3.4. Spatial recording

Using photographic GPS overlays, 26 instances of findings were tracked throughout their positions and coordinates. The details were sourced within a rather constricted geographical zone in the immediate surroundings of the field locations; yet, it should be conveyed that while the spatial arrangement serves to characterize the noted records, the obtained arrangement should not necessarily imply anything concerning the environment or the population condition in the more extended forest area. A coordinate date is available in Table 2.

Table 2: Georeferenced plant observations extracted from GPS overlays in the field photographs

No.	Taxon	Latitude (°N)	Longitude (°E)
1	Flemingia strobilifera	30.368112	77.936721
2	Thysanolaena latifolia	30.368243	77.936557
3	Galium aparine	30.372712	77.936868
4	Youngia japonica	30.371782	77.936373
5	Ziziphus mauritiana	30.371374	77.936105
6	Colocasia esculenta	30.371327	77.936081
7	Euphorbia neriifolia	30.371964	77.936495
8	Colebrookea oppositifolia	30.372310	77.936644
9	Ricinus communis	30.372709	77.936860
10	Pogostemon benghalensis	30.373089	77.937000
11	Calotropis gigantea	30.373322	77.937111
12	Anisomeles indica	30.373948	77.937422
13	Clerodendrum infortunatum	30.374437	77.937643
14	Solanum violaceum	30.376034	77.938387
15	Lepidagathis incurva	30.376881	77.938890
16	Pteris vittata	30.385983	77.941429
17	Acmella paniculata	30.381248	77.940492
18	Hydrocotyle umbellata	30.381286	77.940468
19	Androsace umbellata	30.380815	77.940819
20	Mazus pumilus	30.380905	77.941050
21	Dioscorea oppositifolia	30.380036	77.940547
22	Oplismenus sp.	30.380032	77.940392
23	Jasminum officinale	30.379968	77.940287
24	Carissa carandas	30.379926	77.940228
25	Oxalis corniculata	30.380013	77.940376
26	Triumfetta rhomboidea	30.379749	77.941640

Coordinates were transcribed directly from the GPS overlays embedded in the supplied photographs. They represent photographic GPS records and should not be interpreted as survey-grade positional measurements.

The spatial aspect brings an additional benefit to floristic survey since upcoming field teams may be able to come back to the notes made earlier and check how the flora differs from season to season or year to year. The possibility for repetition is valuable especially with respect to student monitoring, where groups of students may build upon the existing observations instead of starting from scratch. However, the mention of GPS and camera coordinates here means that in the evaluation the coordinates are to be accepted as providing location data only at the field level, but not at the survey level.

3.5 Taking photographs and working with them digitally

The recorded field images become an illustration of what is visible in nature, but they also preserve its morphological features and can be analyzed quickly beside the original data from the field. Some typical cases are given in Figure 2. The presence of an image, taxonomic name and geographical position form the basis of a simple online documentary chain; however, this does not mean that it could substitute a herbarium specimen for cases where taxonomic proof is necessary.

The significance of dataset created on the basis of the observations is widely recognized within the sphere of biodiversity science. iNaturalist is growing at a rapid pace in terms of biodiversity records applicable in scientific publications while research of its identification system shows that participation of the expert community as well as of ordinary participants helps to improve the quality of data (Mason *et al*., 2025; Campbell *et al*., 2023) [2, 8]. The main advantage of the digital workflow in this research is not automation, but creating traceable data.

Fig 1: Representative field photographs of plant taxa documented during the exploratory survey in the Sal-dominated Forest landscape near Dehradun, Uttarakhand, India. (A–Z) Selected photographic records illustrating the herbaceous, shrubby, grassy, fern and climbing vegetation documented during the field exercise. Panel identities correspond to the sequence of records in Table 1.

Table 3

A.	Flemingia strobilifera
B.	Thysanolaena latifolia
C.	Galium aparine
D.	Youngia japonica
E.	Ziziphus mauritiana
F.	Colocasia esculenta
G.	Euphorbia neriifolia
H.	Colebrookea oppositifolia
I.	Ricinus communis
J.	Pogostemon benghalensis
K.	Calotropis gigantea
L.	Anisomeles indica
M.	Clerodendrum infortunatum
N.	Solanum violaceum
O.	Lepidagathis incurva
P.	Pteris vittata
Q.	Acmella paniculata
R.	Hydrocotyle umbellata
S.	Androsace umbellata
T.	Mazus pumilus
U.	Dioscorea oppositifolia
V.	Oplismenus sp.
W.	Jasminum officinale
X.	Carissa carandas
Y.	Oxalis corniculata
Z.	Triumfetta rhomboidea

4. Discussion

4.1. Meaning of 26 records datasets

The analysis of the 26 records demonstrates that a relatively short field survey may result in a diverse set of observations and reflects the presence of 19 families and several growth forms in the area under study. The findings confirm the efficiency of preliminary reconnaissance in biodiversity assessment. However, it should not be concluded that the number of 26 reflects floristic diversity of the area. Various factors contribute to the number of taxa recorded during observations, including observer effort, accessibility of plants, detectability, season, plant phenology, and likelihood of photographing and uploading a particular plant species.

This distinction is of great importance since this study is compared with systematic research in Sal forests. For instance, recent studies conducted in the Central Himalaya on the topic of phytosociology included repeated sampling and measuring the diversity of species to identify the differences in management regimes (Joshi & Joshi, 2025) [5]. Since the reconnaissance dataset does not provide the required structure for sampling, the contribution of the present study oriented towards identifying the taxa and the locations that may be included in subsequent systematic samplings.

4.2. Diversity of understorey and microsites within forests

The presence of ferns, herbs, shrubs, and climbing species indicates that the vegetation studied consists of a mixture of species from different microsite types instead of showing a similar pattern of vegetation composition. Understorey composition in the forest is influenced by several environmental factors, such as light, moisture, soil condition, and disturbance interaction (Landuyt *et al*., 2019; Deng *et al*., 2023) [5, 7]. Thus, it is interesting to note that the presence of forest species and species from open habitats serves as a good basis for checking whether variations in canopy openness, proximity to edges, and humidity are correlated with differences in vegetation composition. The data recorded for roadsides, cultivated territories, and waste lands are of great importance for future disturbance gradient studies. One way of enhancing the quality of research would be to properly measure disturbance levels.

4.3. Digital Biodiversity Records as a Tool for Monitoring

This technique is notable in that it allows us to view all records like data on observations, photos, locations, and species in one place. Such merging is becoming more widely used due to the essence of modern biodiversity study, which requires processing big data (Mason *et al*., 2025) [8]. iNaturalist records can be helpful for research in species distribution and biodiversity, but their usage depends on the reliability of the identification and an understanding of the spatial and temporal bias (Di Cecco *et al*., 2021; Campbell *et al*., 2023) [2, 4]. In local forest monitoring, this means that we can use a tiered approach. The first tier is the simplest and cheapest as it based on taking photos and GPS. The second tier is the stage when taxonomic identification and voucher collecting (if needed) take place. The third tier is when quadrats or transect methods are employed for quantitatively measuring the levels of abundance, frequency, cover, and regeneration. Usage of these tiers over time can provide a proper monitoring framework connecting student research with the up-to-date ecological analysis.

4.4. Taxonomic Verification Represents A Crucial Stage In The System Of Quality Control

The present research has consciously chosen the approach of working identification because the source material has not provided herbarium specimens or formal taxonomic identification in the full sense of this term, which should not, however, be treated as a shortcoming of this specific dataset, as it is common for image-based biodiversity studies when diagnostic characters may be incomplete or taxa may resemble each other visually. Recent studies stress that identification by experts is relevant despite technological progress (Campbell *et al*., 2023; Mesaglio *et al*., 2025) [2, 9]. Therefore, if the publication of the current dataset takes place, a taxonomic quality control stage should be performed. All the records have to be verified against Plants of the World Online or suitable regional flora, and all the doubtful entries should be kept at the genus level (Royal Botanic Gardens, Kew, 2026) [10].

4.5. Educational Value for Forestry Undergraduates

This study also portrays a fruitful intersection between the training in ecology and biodiversity study. The processes underlying students' training involve moving from real-life observations to photography, geolocation, electronic identification, and ecological interpretation. This pathway helps develop the needed practical experience utilized in contemporary forest inventory and biodiversity monitoring. Previous studies show that the potential application of technological solutions, such as iNaturalist and community science, to biodiversity education cannot be underestimated (Aristeidou *et al*., 2021) [1].

Moreover, the possibility of continuity should be noted. If students keep the coordinates and photographs, future classes will be able to go to the same observation points, test identification made at previous occasions, identify new species, and track seasonal/interannual changes. Therefore, instead of a one-off academic task, this process can become a locally sustained biodiversity observation repository.

4.6. Management and Conservation Implications

Even though the current dataset does not provide evidence for formal evaluation of invasiveness, disturbance and conservation status, it brings to light a number of plants and microsite associations that need further research. A management-based reconnaissance could focus on systematic monitoring of disturbance-related species, measuring their coverage along roads and forest edges, and evaluating if their distribution is dependent on light availability and human influence. At the methodological level, the importance of the presented dataset lies in its ability to get an overview on where intensive work should be performed later.

5. Limitations and Future Research

There are some limitations to this research that must be addressed. Firstly, one cannot speak of any sampling approach, as the research does not refer to quadrat size, transect distance, sampling frequency, and replication. Secondly, data on the plant abundance, density, frequency, and percent cover are missing. Thirdly, the results were influenced by detectability, accessibility, and timing of the fieldwork. Fourthly, the plant was identified and spelled according to the initial report but needs confirmation by other experts. Lastly, it has to be remembered that data in the field survey are just observations and must not be treated as experimental data. The term plant records have been chosen according to the relevance of the identification process. In the future, there is a need to incorporate replicated quadrats or belt transects, to note down abundance and cover, to analyze canopy openness and environmental variables, and to repeat observations over several seasons. Taxonomic identification should be improved due to consulting experts and collecting voucher specimens, whenever possible. Furthermore, a good idea is to link the collected GPS points with a sampling grid so that actual records can be processed together with more constant sampling works.

6. Conclusion

The research transforms students' practice into more systematic information regarding the flora of a Sal forest according to the data obtained near Dehradun in Uttarakhand. During the research, 26 plants from 19 families and unusual morphological forms were registered by means of field photography, geolocation, as well as identification using the iNaturalist online service. The attained results clearly demonstrate the potential of IT technologies in collecting and processing horticultural knowledge. The key contribution in science is not in determining floristic richness, but in a compilation of repeatable observations, which form a foundation for future systematic studies. The integration of photographs and coordinates allows creating a repeatable basis for taxonomic validation and quantitative sampling. If integrated with replicated quadrats or transects, and environmental and seasonal monitoring, this survey could become a good monitoring system for years to come.

This study therefore provides practical recommendation for modern forestry: digital tools are most effective when they are used to link observations in the field and formal scientific validation. Their ultimate goal should not be to replace traditional botany, but to enhance the ease of seeing and documenting for future studies.

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