

# Does landscape diversity and organic cultivation practices support biodiversity that render crucial ecosystem services?

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## Background

Conventional agrarian practices have taken a heavy toll on environment. Among other disastrous consequences, agricultural intensification is decimating biodiversity throughout farmlands (Le Féon et al., 2010; Robinson & Sutherland, 2002). Maintenance of biodiversity in farmlands is necessary for delivering ecosystem services (ES) such as pollination, which is essential for crop yield and quality. About 35% of major global crops depend on animal pollination for fruit set (Klein et al., 2007) to varying extents. Additionally, the quality of the fruit also such as fruit size, flavour and shelf life also increase with cross-pollination (Wietzke et al., 2018). Global demand on crops that are pollinator dependent has increased due to their higher nutritional value. Sustainable management of farmlands which support the local biodiversity and in turn strengthen the efficient delivery of ecosystem services such as pollination is imperative.

Another driver which is exacerbating the well-being of agricultural ecosystems is deforestation due to establishment of new agricultural landscapes. Therefore, there is strong empirical support behind the hypothesis that declines in pollinator populations is a repercussion of the processes working at landscape scales (Potts et al., 2010) Not only pollinators, natural vegetation in agricultural landscapes harbours natural predators of agricultural pests by providing resources like shelter, alternative prey base and hibernation habitat (Landis et al., 2003). On one hand, pest infestation is a major reason behind yield loss. On the other hand, pest management by pesticides poses major threat to pollinator (Potts et al., 2016) and natural predator (Desneux et al., 2006) populations. Therefore, management strategies of agricultural landscapes should be developed to maximize the crop yield while maintaining the beneficial arthropod diversity.

Landscape diversity and organic cultivation practices support biodiversity and in particular the functional guilds that render crucial ecosystem services such as pollinators, soil microbiome, and invertebrate biocontrol agents. In this study we aim to use landscape matrices of different land use types and agricultural practices to evaluate the responses of pollinators, invertebrate biocontrol agents and soil microbiomes that are extremely important for crop yield and quality in addition to other ecosystem services that they provide to adjoining landscapes.

## Objectives

RQ1: Impact of landscape diversity on pollinators and biocontrol agents and their function

RQ2: Impact of land management on pollinators, biocontrol agents and soil fauna, and their function

## Hypotheses

- a) The proportion of natural/semi-natural lands in the matrix of homesteads predict farmland insect diversity and biotic interactions useful for sustainable small-scale farming in homestead.
- b) The farm diversity and farm management predict biodiversity and biotic functions in homesteads.

## Site selection

A total of 21 different homesteads that have different composition of usufruct, or restored forests were selected for the present study. All the sites have been selected in the Bichchiya block of Mandla district. Site selection was primarily based on the extent of restored forests in the neighbourhood and by the composition of crops grown in the homesteads. The common crops cultivated and subjected for the present sampling included green peas, pigeon peas, coriander, black gram, mustard, amaranthus etc.

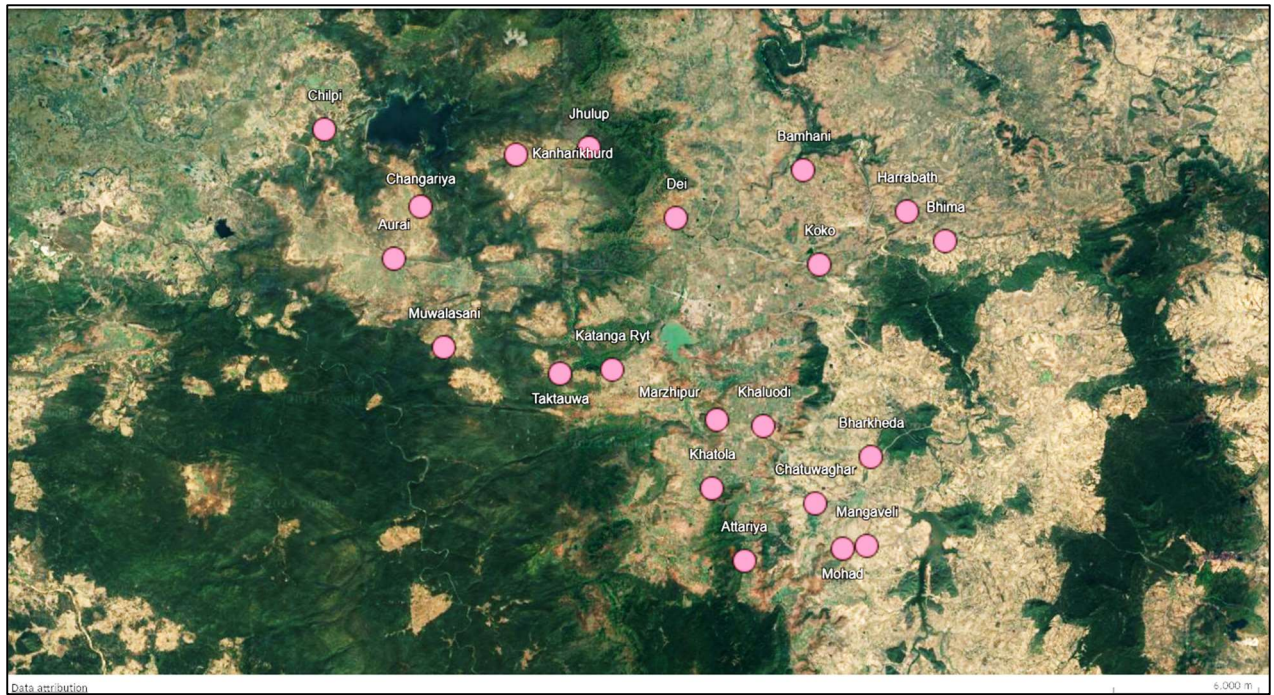


Figure 1: Study location- Bichiyya block with the farms depicted with a circle and village names where the observations were made ©Google earth and map created by Hariraveendra

## Sampling

We have carried out following methods to estimate farmland biodiversity and biotic functions useful for sustainable farming:

1. Caterpillar models – to estimate biocontrol of pests provided by potential predators  
In each homestead, a total of 40 caterpillars were deployed. Among these, 20 caterpillars were affixed to twigs of one meter length since the average height of the crops were around 1 meter, while the remaining 20 were positioned on the ground. The 20 twigs were randomly planted on the ground, each separated by a minimum of 2 meters. Each of the 20 caterpillars affixed to the twigs was alternately green and brown in colour. The remaining 20 caterpillars, affixed to small fragments of sticks, were placed on the ground beneath each of the twigs (10 were green and 10 were brown, arranged alternately). The deployed caterpillars were left unattended on the field for 48 hours. The retrieved caterpillars were subjected to thorough examination for bite, toe and oviposition marks using Low et al., (2014) to identify the potential predators.
2. Malaise traps – to estimate biocontrol of pests provided by potential parasitoids  
In each homestead, we deployed two malaise traps, positioned diagonally opposite to each other along a transect, to effectively represent the site to collect the parasitoids. The traps were revisited 48 hours and the trapped insects were collected and transferred into 125 ml storage vials with ethanol for preservation and subsequent identification using a stereo zoom microscope.
3. Flower observations – to examine plant-pollinator interaction in crop plants  
In each homestead, floral visitor observations were conducted for an hour between 9 am and 4 pm on clear, sunny days. Five random 1\*1 square meter area quadrants with 1 to 5 crops were selected and observed the pollinators with five team members positioned 5 meters apart from each other. The individual bee visitation events to visible flowers within a selected quadrant were observed and counted for 15 minutes duration. This methodology was repeated for one hour in each homestead.

The recorded data included the individual pollinator species and the frequency of their visitation to the flowers. Additionally, specimens of some pollinators were collected and preserved for subsequent analyses.

4. Pan traps – to understand the diversity of flower-visiting insects

In each homestead, 15 pan traps were deployed. A total of five quadrants were selected for pan trap installation in each homestead, with four of these quadrants were positioned at the four corners, while the fifth quadrant was at the center. These traps were arranged in 5 triplets, with each triplet comprising three colored pans: blue, white, and yellow. We used dissolved detergents as a killing agent for trapping the insects. The traps were retrieved after a 48-hour period, and the collected insect samples were subsequently stored in ethanol for preservation.

5. Leafcutter bee reproduction – to estimate the activity of leafcutter bees – a prominent group of pollinators of legumes

We used the characteristic notches bees leave on the leaves to estimate leaf-foraging sources of leafcutter bees. Out of the plants available in each homestead, 10 quadrants each of 1m x 1m is randomly selected and all the plants in the selected quadrants are thoroughly surveyed for the leaves with characteristic urn shaped marks made by the leafcutter bees while cutting the leaf pieces for their nest.

6. Pitfall traps – to examine the diversity of soil-dwelling insects and particularly the ground beetles – the potential predators of insects pests

In each homestead, we installed ten pitfall traps along two transects ((ANTS: Standard methods for measuring and monitoring biodiversity, 2000)). We used 50 ml of 75% isopropanol as a preservative. After 48 hours, the pitfall traps were retrieved, and the contents were transferred into 125 ml wide-mouth bottles filled with ethanol for preservation for subsequent identification.

7. Farm-level data – to characterize the nature of human settlements

The building type and other man-made structures can provide nesting opportunities for bees and wasps – two crucial functional groups for pollination and pest control. We have recorded the type of house – kachcha or pucca, fence types, vegetation diversity in the human settlements.

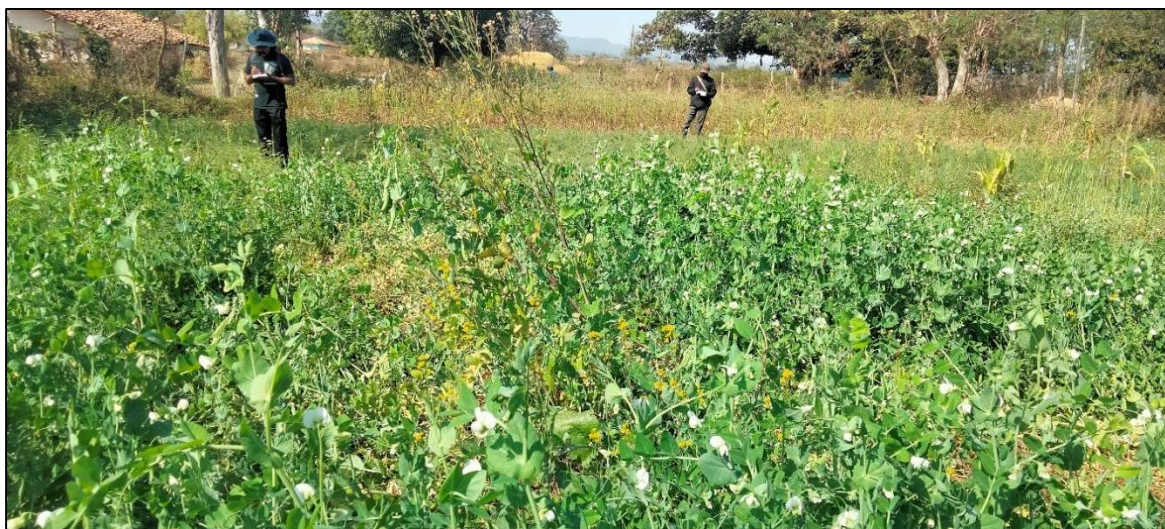


Figure 2: A vegetable garden of a representative homestead (©Gopika Viswan)

## Initial results:

Caterpillar models – to estimate biocontrol of pests provided by potential predators

We used caterpillar models to estimate insect pest predation function in vegetable gardens of homesteads. Since both the epigeal and arboreal predators provide the service of biological control of the pests, we sampled predation on caterpillars that are kept on ground and plants. In order to provide a diversity of pest caterpillars, caterpillars of green and brown colors were used in the study.

In our study, a total of 840 caterpillars were used. Out of these, 318 were subjected to predation, accounting for 38.17% of the total caterpillar models. Six caterpillars were missing and could not be retrieved from the field. Arthropods were responsible for 26.63% of the predation, with major predators including spiders, ants, locusts, beetles, and wasps. Avian predation constituted 6.38% of the total, while mammalian predation was recorded at 5.52%, with mice and rats identified as the primary mammalian predators. Reptilian predation was the least prevalent, accounting for 1.91% of the total predation observed. The overall predation rate was significantly higher among the caterpillars placed on the ground (50.1%) compared to those affixed to twigs (26.24%). Among the caterpillars attacked by arthropod predators, 33.33% were positioned on the ground while 19.95% were on the twigs. Bird predation affected 6.7% of caterpillars on the ground and 6.1% of those on twigs. Reptilian predation accounted for 3.34% of ground-dwelling caterpillars and 0.48% of caterpillars on twigs. Mammalian predation exhibited a higher rate among caterpillars placed on the ground (9.82%) compared to those on twigs (1.23%).

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*Caterpillars on ground are more often predated than on plants/poles suggesting the crucial role of ground-dwelling insect predators*

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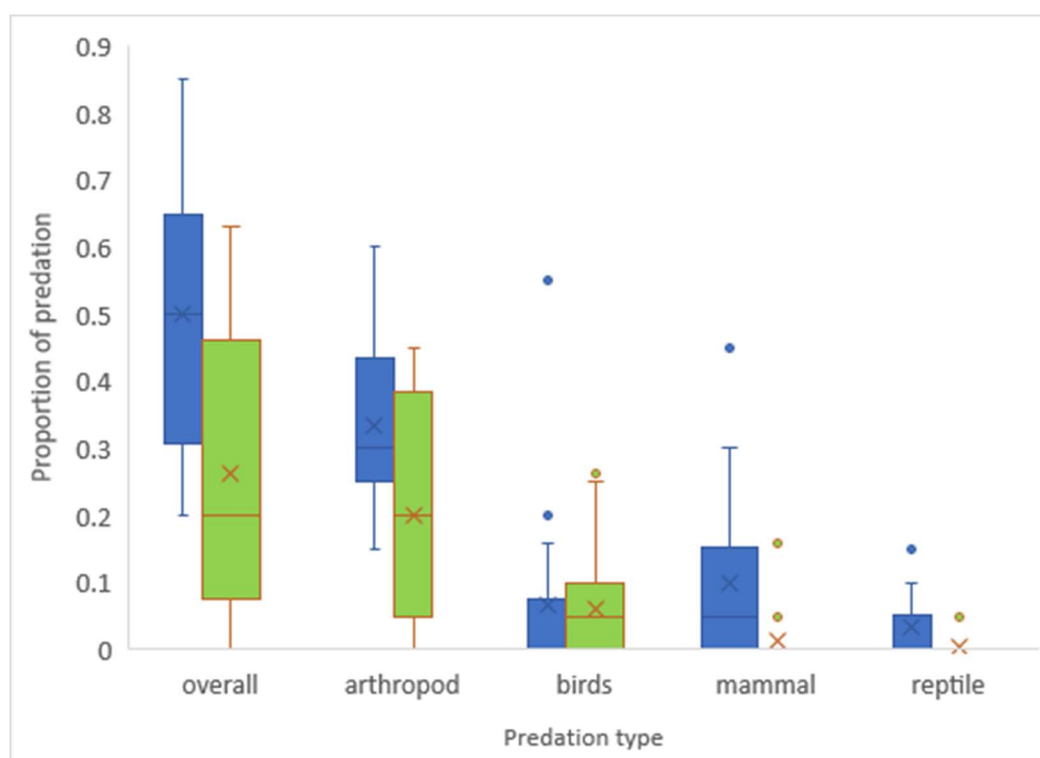


Figure 3: Proportion of predated caterpillars on ground (blue) and plants/poles (green)



Figure 4: Caterpillars with bite marks of insects/ spiders, (©Gopika Viswan)

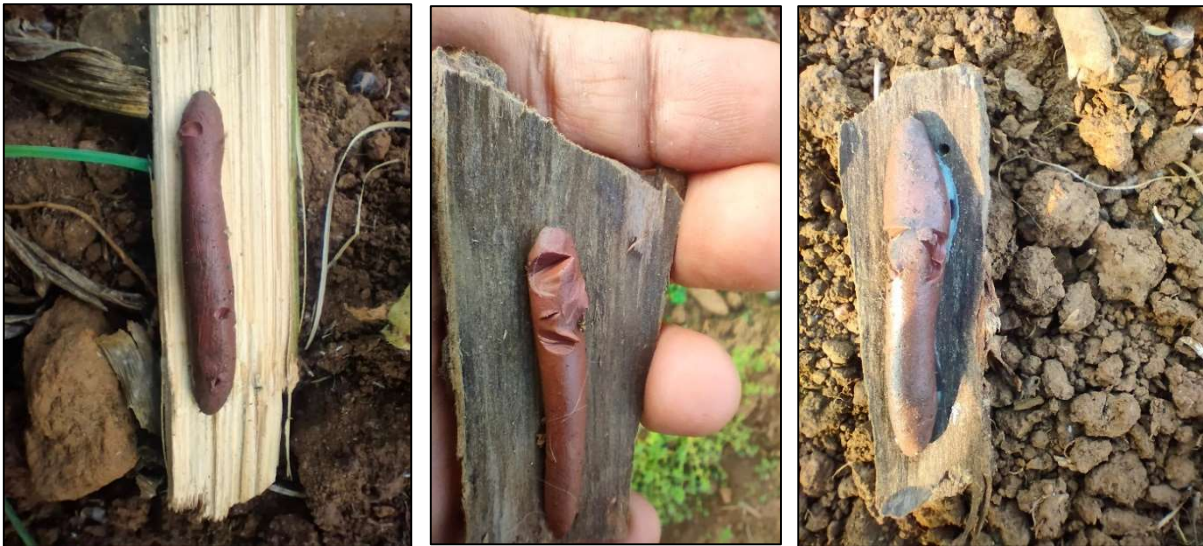


Figure 5: Caterpillars with the beak marks of birds, (©Gopika Viswan)



Figure 6: Teeth marks of reptiles on caterpillar models, (©Gopika Viswan)

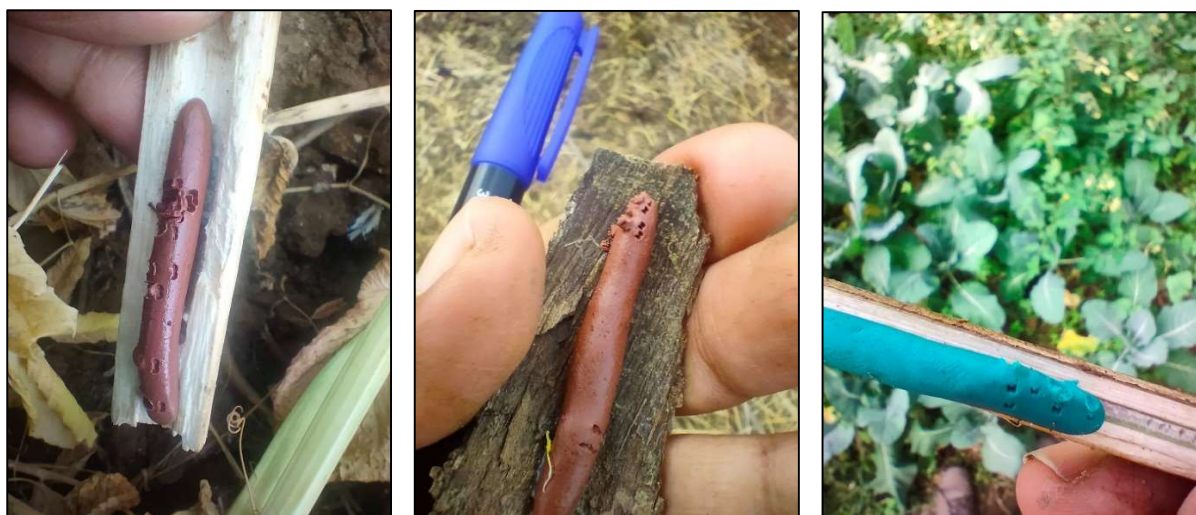


Figure 7: Bite marks of mammalian predators, ©Gopika Viswan

### Estimation of leafcutter bee activities in homesteads

We used pigeon pea to estimate the activity of leafcutter bees in the homesteads. We used the characteristic notches left by the bees on the leaves to estimate it. Out of the plants available in each homestead, 10 quadrants each of 1m x 1m is randomly selected and all the plants in the selected quadrants are thoroughly surveyed for the leaves with characteristic urn shaped marks made by the leafcutter bees while cutting the leaf pieces for their nest. Total number of leaves and the number of leaves having the urn shaped marks are recorded for each plant. Total height of the plant is also recorded. The length and width of the middle leaf of a plant randomly selected in a quadrant is also recorded.

Table 1: Total no. of quadrants, plants and plants with cuts in each study site

Sl. No.	Study sites	Total no. of quadrants surveyed	Total no. of plants	Total no. of plants with cut	Proportion of plants with cut (%)
1.	Attariya	10	112	8	7.14
2.	Bamhani ryt	10	118	2	1.69
3.	Barkheda	10	96	52	54.16
4.	Chatuwakhar	5	40	20	50.00
5.	Dei	10	102	21	20.58
6.	Harabath	10	68	11	16.17
7.	Jhulup	10	121	8	6.61
8.	Khalodi	10	93	21	22.58
9.	Kanharikurth	8	72	15	20.83

10.	Katanga ryt	10	89	25	28.08
11.	Khatola	4	30	23	76.66
12.	Koko	10	107	26	24.29
13.	Mangabeli	5	49	4	8.16
14.	Manjipur	10	99	35	35.3
15.	Taktawa	10	108	5	4.62
Number of plants surveyed from 15 sites- 1303					
Number of plants with leafcutter cuts in the leaf- 276					
Proportion of plants with cut in the leaf in the study- 21.18%					

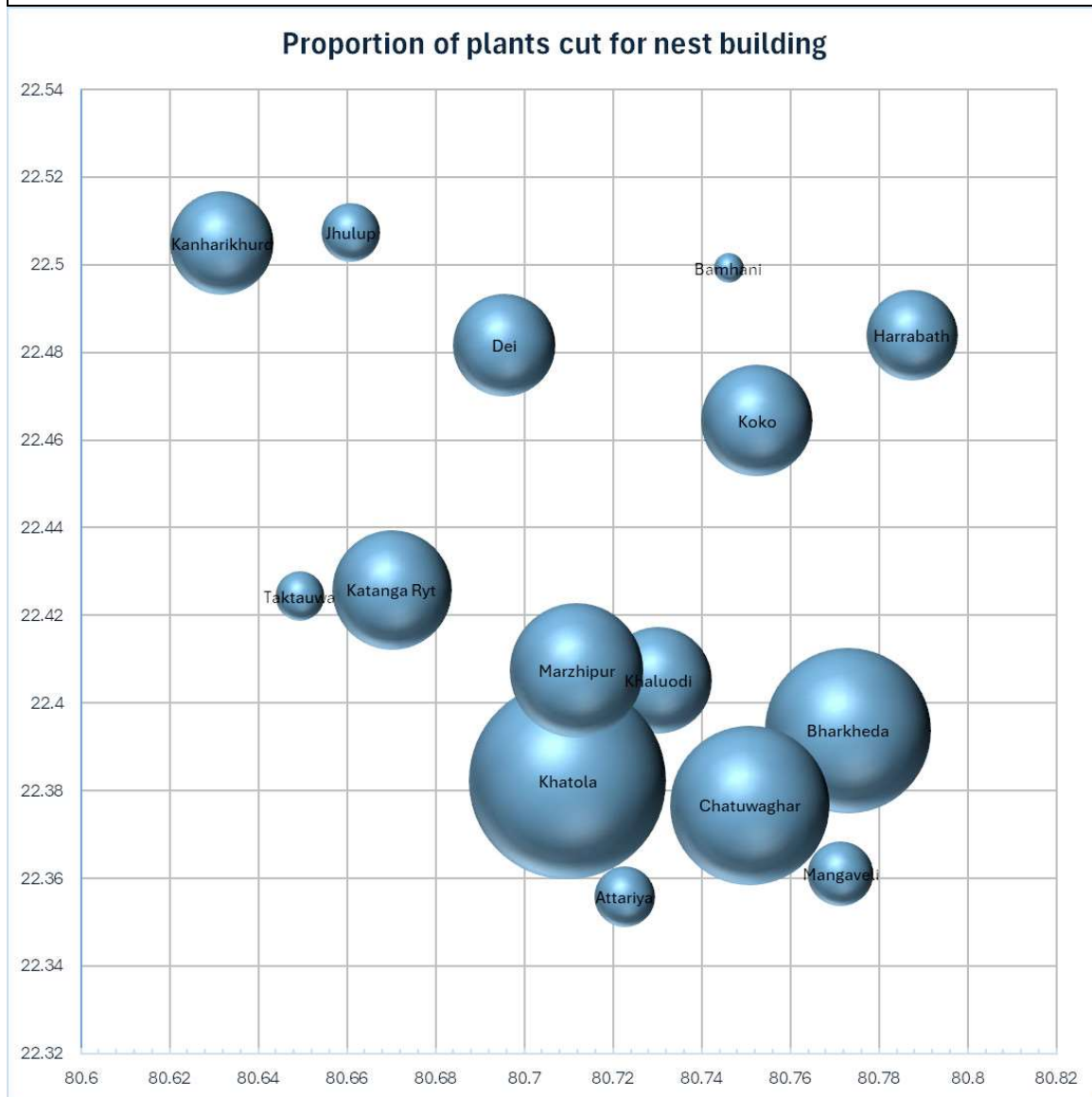


Figure 8: Proportion of plants cut for nest building. The size of the bubble depicts the proportion of plants from which leaves were harvested

Out of the 15 sites surveyed, Khatola had the highest proportion of cut leaves with 76.66% plants having the leaves with cut even though the number of plants surveyed is the least among the 15 study sites, followed by Barkheda with 54.16% and Chatuwakhar with half proportion of plants with cut marks on the leaves. Bamhani ryt and Taktawa recorded the least number of plants with cut marks, i.e. 1.69% and 4.62% respectively. 60% of the sites recorded more than 20% of plants with cut while the remaining 40% of the sites recorded plants with cut at a proportion of 1% to 20%.



Figure 9: A pigeon pea leaflet cut by a leafcutter bee, ©Ashly Baby

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## Acknowledgements

Manohar Pawar and Pradyumna Acharya from Foundation for Ecological Security (FES) supported with the site selection and Snehal (FES) provided the field support. We are very grateful for their contributions.

## Appendix



Figure 10: Malaise trap, © CUK



Figure 11: Pan traps, © CUK



*Figure 12: Pitfall trap, © CUK*