FARMERS FIELD SCHOOL CURRICULUM FOR POLLINATION MANAGEMENT IN NEPAL

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Compiled for the Darwin Initiative project:

Embedding Sustainable Pollination Management into Nepalese Agricultural Systems

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Contents

Notes on authorship: This document is produced by the Darwin Initiative project team with contributions from the University of Bristol, Agriculture and Forestry University Nepal, LI-BIRD Nepal, HERD International and Central Department of Zoology, Tribhuvan University. The document is based off a Farmer Field School syllabus developed by the FAO Global Pollination Project but has been heavily modified and expanded.

Topic 1: Farmer Field School (FFS) introduction

- What is a FFS
- Objectives of FFS
- FFS Principles
- Principles of integrated production, pest and pollination management (IPPPM)
- Participatory planning of FFS activities
- The FFS core activities
- Steps in FFS Implementation
- Monitor and evaluate the FFS session

Learning goal:

By the end of the FFS training the participants will be able to:

- Introduce the FFS methodology to the community and FFS members.
- Explain the FFS process and methodology
- Adopt the methodology in to action to conduct FFS related to pollination management in Nepal.

Learning concept:

The learner will learnt about how to conduct a FFS for pollination management in horticultural (vegetables) crop in Nepal.

Facilitation methods:

Small group discussion, short questions, group dynamics, role plays, class room presentation, BBT

Materials required:

Flip charts, marker pens, documentary show.

Suggested time:

Three hrs classroom presentation and one hr. documentary show.

Learning materials:

1. What is a FFS

Farmer field schools are traditionally an adult education approach, a method to educate farmers in an informal setting within their own environment. FFS are “schools without walls” where groups of farmers meet weekly with facilitators. FFS are a participatory method of learning,

technology development, and dissemination based on adult learning principles such as experiential learning. The defining characteristics of FFS include discovery learning, experiential education, farmer experimentation, and group action.
The approach is an interactive and practical method of training, and empowers farmers to be their own technical experts on major aspects of localized farming systems. It assumes that farmers already have a wealth of knowledge. Farmers are facilitated to conduct their own research, diagnose and test problems, and come up with solutions. FFS training programs help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions. Through group interactions, attendees sharpen their decision making abilities and their leadership, communication, and management skills.

A typical FFS entails one or two-three crop seasons ie covering the year round cropping system, of hands- on, farmer experimentation and non-formal training to a group of 20-25 farmers. The group is responsible for the care and maintenance of the study enterprise covering all aspects of the cropping cycle, from soil preparation, through planting, weed control, pest and disease control, harvesting, post storage to marketing of produce. The approach is a season-long training following a crop phenology. The field is the "teacher" and its conditions define the curriculum while the plants form the most important learning material. By following the whole cycle of the chosen enterprise farmers gain skills and learn to make management decision applicable to any stage in the crop development cycle.

As an extension approach, it is a dynamic hands-on, innovative and participatory discovery learning process built upon the principles of adult education. Every learner is a potential trainer and the facilitators must be technically strong. FFS enable farmers to discover and learn about their own agro-ecology and integrated management. On the basis of this knowledge, they become independent and confident decision-makers- experts in their own fields. A field school therefore is a process and not a goal.

2. Objectives of FFS

FFS is not about technology but about people development. It brings farmers together for them to assess their problems and to seek ways of addressing them.
Specific objectives of FFS are:

- Empowering farmers with knowledge and skills
- Sharpening the farmers ability to make critical and informed decisions that render their farming profitable and sustainable
- Sensitise farmers in new ways of thinking and problem solving
- Help farmers learn how to organise themselves and their communities
- Enhance relationship between farmers, extension and researchers to work all together in testing,assessing and adapting a variety of options within their specific local conditions.

3. FFS Principles

What the farmer wants rules!
Farmers decide what is relevant and needs to be addressed in the FFS, not the facilitator. The facilitator only guides the farmers in their learning process by creating opportunities for experiences.

Learning by doing
Adults learn better from experience than from demonstration or presentations. People do not change their behaviour just because someone tells them what to do or how to change.

Learning out of mistakes
Behavior changes require time and patience. Learning is an evolutionary process and is characterized by free and open communication, confrontation, acceptance, respect and the right to make mistakes as we tend to learn more from mistakes than successes.
Each person's experience of reality is unique

Learn how to learn
Farmers are learning the necessary skills to improve their observation and analysis of their own problem and to take conscious decisions. They learn how they can educate and develop further themselves.

Problem-posing/problem-solving
Problems are presented as challenges, not constraints. Farmers' groups learn different analytical methods to gain ability to identify and solve any problem they might encounter in the field.

The Field is the learning ground
The field is the main learning tool and all activities are conducted in the field. Farmers learn directly from what they see, collect and experience and not from a text book, pictures or other extension materials. Also, farmers produce they own learning materials such as drawings of what they observed in the field. The advantages of these home-made materials are that they are consistent with local conditions, less expensive to develop and owned by the farmers.

Extension workers are facilitators not teachers
In FFS, extension workers are called facilitators because their role is to guide the learning process ("make it easy") and not to teach. The facilitator contributes to the discussions aiming to reach consensus on what action needs to be taken. FFS facilitators are trained in a formal Training of Facilitator (TOF) organized by a recognized FFS master trainer.
In FFS, researchers/ subject matter specialist learn to work in a participatory and consultative way with farmers to provide technical and methodological backstopping support

Unity is strength
Empowerment of farmers through collective action is essential. Not only farmers united in a group have more power than individual farmers but also being recognized as an active actor within a group enhance the social role of individual within a community.

Every FFS is unique
Topics should be chosen by the community. Training activities have to be based on the gaps in farmers' knowledge taking into consideration their level of understanding. Because every group is different with different needs and realities and participants develop their own learning content, each FFS is unique.

Systematic training process
All FFS follow the same systematic training process. The key steps are observation, group discussion, analysis, conclusion and action plan. The training process uses agro-ecosystem analysis approach and is developed gradually during regular and frequent meetings. Experience shows that better results are achieved with weekly meetings than with less frequent FFS sessions. The length of the FFS depends on the enterprise but with livestock it is usually a full year cycle to allow all seasonal variations to be studied. In case of FFS on crops the length is usually equal to the cycle of production; from land preparation to harvesting. Increasingly, FFS include marketing and processing activities. The cycle of the FFS is therefore longer and may continue for years.

4. Principles of integrated production, pest and pollination management (IPPPM)

IPPM is a farming practice where farmers try to balance the ecological aspects with the economic aspects in their farms or business. Thus the goal of IPPM is sustainable production. Such practices include: mulch, manure, crop rotation, rest the garden, cover crops, loosen the soil structure, organic matter, green manure, reducing the use of pesticides that kill beneficial insects along with pests, providing patches of wild biodiversity on-farm (flowering weeds, woodlots, nesting sites) to encourage pollinator populations etc.

In the FFS, emphasis is in growing a healthy crop in a way that is supported by a well-functioning agroecosystem and its services: natural pest control, pollination, nutrient cycling via decomposition of organic matter and good soil structures and soil protection, to give some examples. The training methodology involved is based on learning by doing. The five major principles of IPPM are:

a) Growing a healthy crop in a healthy soil
A healthy crop is able to defend itself against pest and disease attack and to compensate for any damage. The main requirement for obtaining a healthy crop is to maintain a healthy soil and a healthy seed.

- Site selection and seed is important.
- Timely seedbed preparation, planting and weeding in accordance with the specific growth stages of the crop.

A healthy Soil
Soil - is the place where plants live in and feed from. Fertile soil is characterised by a loose texture, a composition rich in nutrients and organic matter, high water retaining capacity and high activity of living organisms.

Practices that help maintain soil health
Ploughing or hoeing

- Plant residues and fertilisers are turned and put under the soil, decompose faster.
- Oxygen content of the soil increases, which favours the development of bacteria decomposing the organic matter, and;
- Compacted parts that have been trampled become loose again for ease of germination.

Addition of organic matter and nutrients: Sources of organic matter;

- Farm manure, droppings of any kind of livestock, often mixed with leftovers of feed. This should ripen for about two weeks before applying to the crop.
- Compost, i.e. decomposed plant material, e.g. from the kitchen and garden waste, or crop harvest residues.
- Green manure, i.e. an inter-crop that does not compete with the main crop and preferably can fix nitrogen from the air. The green manure crop should be trimmed regularly after which the cut parts are left as mulch on the soil surface or incorporated into the soil.

b) Observing the crop and its environment regularly

Why do observation? It is key to appropriate crop management decisions:

- By observing the field and surrounding environment thoroughly and regularly, farmers will intimately know the conditions of the field and are likely to know upcoming problems in time.
- With weekly observations, farmers are able to anticipate problems.
- Under some weather or water supply conditions, pest populations develop more rapidly than natural enemy population.
- The actions to taken at any time should be based on observed conditions.
- After each observation we should determine when to have the next observation, based on the conditions found in the field.

This should be done in the morning hours - before 10.00 a.m. because later in the day the sun becomes too hot causing insects to hide in cool dark places.

Observations are made of the following;

- Soil conditions (structure and moisture).
- Plant health status, based on colour, presence of water and nutrient deficiency symptoms.
- Plant Development, based on measuring the growth and observing size
- Pest and disease attack symptoms, number and types of pests and natural enemies
- Rates of pollinators visiting crops; their numbers and types
- The age of the crop is noted
- Weather conditions
- Observation of the surrounding environment - helps to identify and understand sources of problems that appear in the field (for example, weed incidence)
- Condition along the edge of the field buns, ditches, roads with regard to potentially harmful plants and animals (weeds pests or beneficial ones (Natural enemies), plants providing food and shelter for pollinators and natural enemies, locations of pollinator nesting sites to protect).
- Condition of the neighbouring fields with regard to crop damage as an indicator of the existence of a source of pests and/or diseases.

c) Conserving the natural enemies

Nature's law is that "Larger animals have long generation times and few offspring while small ones have short lifecycles and many offspring." Many insects, like aphids can produce more than 100 offspring per female and their generation times can be for shorter than one month.

Question then, why are we not drowning in insects?

Answer is because there are many mortality factors that reduce the growth of insects and all living things. In addition to unfavourable environmental conditions, population growth of all living organisms is regulated by natural enemies.

What is a natural enemy?

Is a living organism that kills injuries or causes disease in other living organisms. Three kinds of Natural enemies; Predators, Parasites, Pathogens

Predators: Animals that hunt and eat other animals e.g. tigers, spiders and lady bird beetles. They have to consume many prey individuals in order to live. Their bodies are designed to hunt, catch, kill and eat prey. They generally have strong teeth or mouth-parts, sharp vision and strong legs.

Examples of predators - Earning, Rove beetle, Spider, Ladybird beetles, Ants, Lace wing nymph, migratory ants etc.

Parasites: Consume other organisms but by entering the body of their victims and obtaining nourishment from their fluids and tissues, which weakens or even kills the victims - the victim is called HOST. The developing larva of the parasitic insect lives in or on the egg or body of the host, slowly weakening the host insect, which thus cannot complete its development. Insect parasites can be classified as follows:

- Egg parasites lay their eggs in the eggs of other insects
- Larval parasites lay their eggs in or on the larval stage of other insects
- Pupal parasites develop in the pupal stage of other insects
- Some parasites develop in the nymphal or adult stage of their hosts.

Examples of parasites are species of wasps or flies (bracon aphidus).

Pathogens: Micro-organisms that cause disease. They enter the body of their host, living and multiplying within and hence weakening and finally killing the host. Some pathogens require more than one kind of host in order to complete their life cycles. Bacteria, fungi and viruses are kinds of pathogens. Insects attacked by pathogens are usually swollen, exhibit colour changes, move slowly, often stop eating and may be covered with a powdery substance.

Example of a pathogen is a bacterium called Bt which is produced and used as a biological pesticide (for example, Diplel WP, a brand of Bt). This pathogen kills several kinds of pests but does not affect most natural enemies.

d) Make the farm pollinator-friendly

Pollinators are animals (usually bees, or other insects) that carry pollen from the male to the female parts of plants and thus ensure that fruit or seeds are formed. They are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fiber crops.

Making small changes to a farm to make it pollinator-friendly does not require a lot of work. Subtle changes in farm practices can involve identifying and protecting nesting sites and forage; keeping rotations of crops that attract pollinators within an area of one hundred yards; allowing some crops like lettuce, or legume cover crops to bolt and flower before plowing them under; or changing how pesticides are applied in order to have the least impact on native pollinators. This guide will review how pollinator-friendly practices can be incorporated into good farming practices throughout the growing season.

e) Empower the farmer as a decision maker

As adults the farmer learns best through hands on experience - relating the subject matter to their every day experiences and activities, they are encouraged to explore and discover for themselves. The abilities, knowledge and experiences are used for informed decision making about the relative merit of management options for better economic gain.

5. Participatory planning of FFS activities

The Objectives of participatory planning are to make farmers own the process, focus on the activities most important, pool resources together, enable monitoring of the process, allow accountability/transparency, and enhance sustainability of the FFS process and to avoid wastage resulting from duplication of activities.

Three steps are involved in participatory planning: 1) Problem analysis and Ranking, 2) Identification of solutions and 3) Development of the learning programme.

The participants will seek a joint understanding of the farmers' problems on crop pollination. Share insights into the potential and constraints of the enterprise of that FFS. (Analysis of cause-effect relationship of specific problems). Prioritize the problems and identify which problems the FFS will tackle. Identify when in the cropping calendar the problem occurs, so that the solution/time to address the problem can be placed in the seasonal organisation of activities.

6. The FFS core activities

The FFS core activities are the main activities to facilitate the learning process. These activities are normally repeated in each FFS session and include:

- Agro-ecosystem analysis (AESA)
- Group dynamic exercises
- Field comparative Experiments
- Special topics

7. Steps in FFS Implementation

There are about 10 steps that we follow in implementing FFS. These steps are basically grouped into 3 phases.

Phase 1: Preparatory

Step 1: Pre-conditions survey
Step 2: Training of Facilitators
Step 3: General Ground working

- The initial survey
- sensitisation meeting
- Identification of the focus enterprise (entry point)
- Identification of the participants
- Identification of the learning site

Step 4: FFS establishment

- Participatory introduction of participants
- Levelling of expectations
- Setting of learning norms
- Host team
- Participatory planning
- Problem analysis and ranking
- Identification of solutions
- Development of the action plan
- Participatory monitoring and evaluation.

Phase 2: Implementation

Step 5: FFS sessions with core activities
Step 6: Exchange visit
Step 7: Field day
Step 8: Graduation

Phase 3: Post FFS Graduation

Step 9: Post graduation activities

- Continuation FFS activities
- Follow up
- FFS Networks
- Income generating activities

Step 10: Creation of farmer run FFS

8. Monitor and evaluate the FFS session:

It is important to track whether the FFS is achieving its aims and to make corrections if necessary. This means monitoring activities in the daily FFS sessions. Specific tools are described in detail to

help the facilitator introduce the concept of PM&E and to monitor the FFS on regular basis. This allows them to: gain an overview of progress and to enhance the participants' confidence and motivation; draw lessons learned and stimulate corrective action, thus improving the quality of next FFS; and get an early warning of problematic activities and processes that will need corrective action. Regular monitoring will also empower the FFS group by creating opportunities for them to reflect critically on their own progress, the direction of the FFS and to decide on improvements.
The list below gives some examples of participatory methods for PM&E that suit the FFS sessions:

- Evaluation wheel
- How full is the glass of milk
- Mood meter

Pictures can be understood by all, including illiterate, and can be used to visualize the types of changes in the area. Sketches (and maps) can be made by the FFS participants at the beginning of the FFS season (for assessment and planning purposes), during the FFS (for monitoring purposes) and at the end of the FFS (for evaluation purposes) in order to locate the changes and to analyze their causes and effects. Many different items of interest can be addressed including villages/ communities, social status, resources, etc.

The objective of PM&E is to provide an example of how a map or sketch can be used to measure change. The example given is to measure farmers' adoption of appropriate technologies. It may need different materials eg. flip charts, paper, markers of different colours, scissors, glue, local materials etc.

Questions to facilitate understanding

1. What is a Farmer Field School?
2. What are the basic principles of IPPPM? Explain how IPPPM is environmentally safe production model?
3. What are the phases of IPPPM?
4. What are the Natural Enemies? How they are helpful for crop pollination and production?

Topic 2: Basic concept of pollination

- Floral structure, the parts and their functions
- Co-evolution and mutualism between flowering plants and their pollinators, the pollination rewards
- Definitions and concept of cross pollination, self-fertile, self-sterile, cross-compatible, monoecious, dioicous, parthenocarpic etc..

Learning goal:
To understand the relationship between flowering plants and their pollinators, the concept and function of pollination.

Learning concept:
The participants will learn about floral structures, the function of different parts of a flower, thre mutualism between plants and pollinators, the concept of pollination (self and cross) in self-fertile, self-sterile, monoecious and dioecious plants.

Resources to be used:
Flowers of different kinds, floral diagram, flip charts, markers, adhesive tape and magnifier

Time taking:
This exercise will require about an hour of formal presentation, and at least two hours encouraging the participants to gather flowers and examine the pollination structures.

Procedure:

- Introduce the topic to the participants and explain all of the pollination theory, drawing diagrams of floral structures on the board.
- The facilitator should make use of the following information to explain the learning concepts, using handouts and drawing on the flipchart.
- The participants should gather flowers in bloom. Using magnifying glasses, they should identify the parts of the flowers (petals and sepals, stamens, stigma and ovaries).
- For each flower, the participants should discuss why they think it has the features (e.g., shape or colour) that it does and how these features may be useful for attracting pollinators.
- Then participants should engage in a group discussion, brain storming and solve the assignment provided to them at the end of session (see questions at end).

Learning materials:

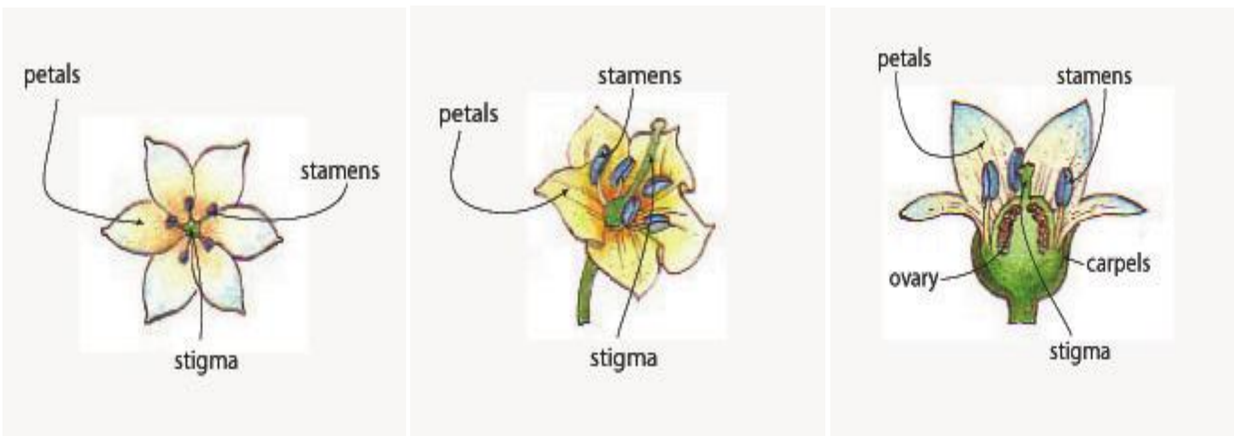
1. Floral structure, the parts and their functions

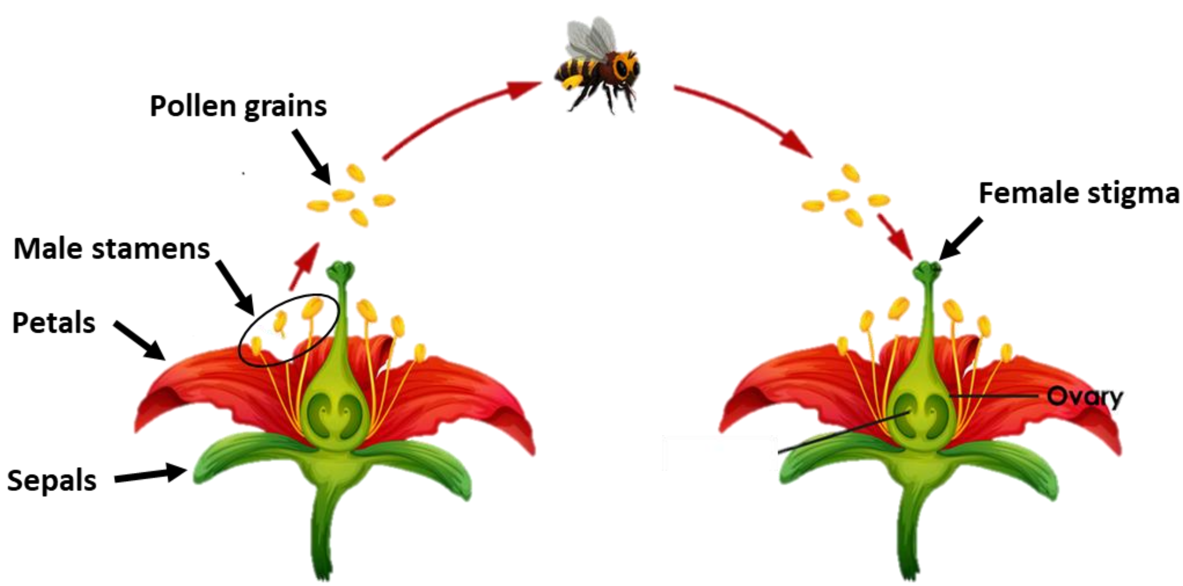
Typically a flower is made up of four critical parts:

- Petals and sepals, also known as the corolla – this is for the attraction of pollinators and provides a landing platform for flying insects;
- Stamens which produce pollen;

- Stigma and ovaries that receive pollen and develop ultimately into seed or fruit.
- Nectaries which are located inside the flower and produce sweet-smelling sugary nectar which serves as a reward, to attract flying insects.

Colored petals attract the pollinators and provide a landing platform for flying insects. The stamens are the male reproductive parts which produce large quantities of pollen which is the equivalent of sperm in plants. Pollen is rich in protein and fats and is very nutritious for many insect pollinators. The stigma is the female reproductive part of a flower and is covered in a layer of sticky substances which captures pollen. Most flowers also have glands called nectaries which excrete a sweet sugary substance called nectar which is very attractive to pollinating animals. Nectar has no important function for the plant, its only purpose is the attract pollinators and provide an energy-rich reward for animals that come to visit the flower.





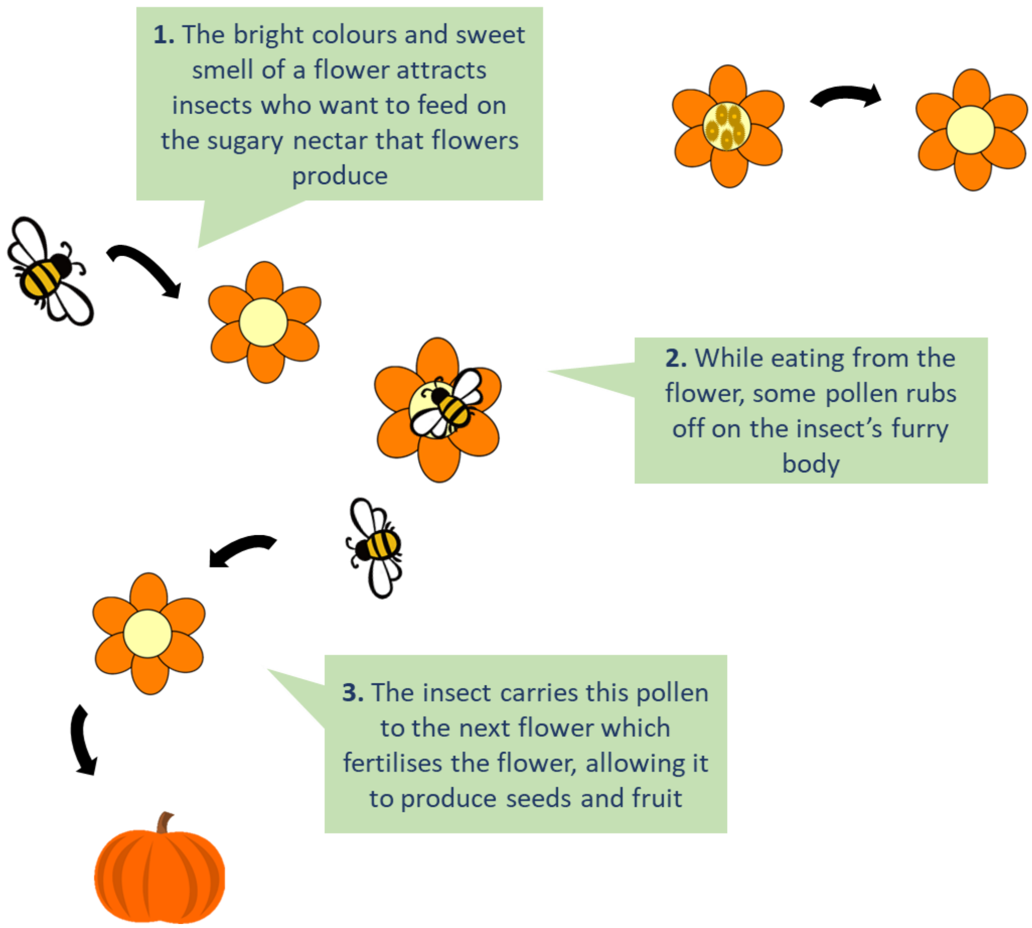
Flowers vary a lot in their shape, size, color and the amount of nectar and pollen they produce. Many of these differences between flowers have evolved to meet the specific needs of pollinators, or attract pollinators of a certain type.

The aim of a flower is to attract a pollinator, cover the pollinator in pollen and then make sure that the pollinator goes on to visit another flower of the same species. If the pollen and nectar was too easy to get, lots of animals would steal it and not provide any useful pollination service to the plant. This is why there are so many different shapes, sizes and colours of flower – they are all trying to attract pollinators in different ways and make sure that they transfer as much pollen as possible.

2. Why plants need pollinators and why pollinators need plants

Unlike animals, plants are not able to move around – they are fixed in one place. This creates a challenge when they need to mate because they can't travel to find a partner. Instead, plants use pollen (which is a bit like sperm) to reach other plants and fertilize them. Pollen can move between plants in many ways. Some plants rely on the wind to move their pollen, but others have evolved a close relationship with animals who carry their pollen from one flower to another. The plant benefits from having its pollen moved and the animal benefits from feeding on the nutritious nectar and pollen provided by the plant.

Animal pollinators gain a rich supply of energy from the sugars found in nectar and lots of nutritious proteins and fats from pollen grains. For some animals (like many wasps, flies, beetles and birds), this nectar and pollen just supplements their existing diet. But for other pollinators like bees, nectar and pollen are the only things that they eat, so they are completely reliant on flowers for their survival.



3. Definition and the concept of cross pollination

Not all flowering plants have the same pollination requirements – some plants can pollinate themselves and do not need pollinating agents like wind or animals to carry their pollen. Some plants can partially self-pollinate but the process is improved by pollinating agents, and some plants are almost entirely reliant upon animals or wind to move their pollen.

Cross-pollination is the transfer of pollen from flowers of one plant to the flowers of a different plant or different variety. Many crops require or benefit from cross-pollination.

Self-fertile plants can develop seeds and fruit when pollen is transferred from anthers of a flower to the stigma of the same flower or different flower on the same plant. However, such plants are not necessarily self-pollinating. Insects still may be necessary or helpful in moving pollen to the stigmas. A good example of this are beans and tomatoes.

Self-sterile plants require pollen from a different plant or even a different variety. If the plant requires different varieties, the grower must interplant pollinizer varieties with the main variety.

Cross-compatible varieties are receptive to each other's pollen, whereas *cross- incompatible* varieties are not. A good example of this is an apple tree.

Sometimes, a flower has only male or female parts. An example of this is most squashes and melons, e.g., pumpkins. Monoecious plants have both male and female flowers on the same plant. Dioecious plants have only one sex of flower on the same plant. Having separate male and female flowers makes cross-pollination totally essential. For these plants, their dependence on animal pollinators is almost 100%.

Parthenocarpic plants develop fruit without requiring the pollination process, and that being the case, parthenocarpic fruits can be partially or completely seedless. An example of this is bananas, that reproduce by suckers, not by seed.

	Self-Pollination	**Cross Pollination**
Definition	Self-pollination is the transfer of pollen grains from the anther to the stigma of the same flower	Cross pollination is the transfer of pollen grains from the anther of a flower to the stigma of a flower of a different plant of the same species.
Plant examples:	Peanuts, peas, wheat, barley, oats, rice	Apples, plums, pears, raspberries, blackberries, strawberries, runner beans, pumpkins, buckwheat
Pollen transfer:	Shed pollen directly onto stigma.	Wind, insects, water, animals, etc.
Plant differences:	Smaller flowers.	Brightly coloured petals, nectar and scent, long stamens and pistils.
Results:	More uniform offspring. Allows plant to be less resistant as a whole to disease. However, it does not need to expend energy on attracting pollinators and can spread beyond areas where suitable pollinators can be found.	More variety in species. It allows for diversity in the species, as the genetic information of different plants are combined. However, it relies on the existence of pollinators that will travel from plant to plant.
Number of pollen grains:	small number	large number

Questions to facilitate understanding:

1. What are the main parts of a flower and what are their functions?
2. Why do plants need pollinators?
3. Why are insects attracted to flowers?
4. What is self-pollination, what is cross-pollination and give a few examples of each?

Some examples of important cross-pollinated crops in Nepal:

Topic 3: How pollination occurs

- What is pollination?
- Different methods/modes of pollination
- The diversity of insect pollinators
- Pollinators' morphology

Learning goal:
To understand the mode of pollination the means of pollination and the morphology of pollinators it matches for pollination services.

Learning concept:
The participants will learn about the means of pollination and the natural pollinators, the mode of pollination, the pollinators' morphology and the special appendages for pollination service

Resources to be used:
Important pollinators, cross-pollinating crops, video, a honey bee or more than one (or any other pollinator that is common), display board, color pens.

Duration
The facilitator should spend about 1 hour in a class room to explain what pollination is and then they have to carefully observe the morphological view of important pollinators e.g., honeybee. As far as possible, they have to prepare the list of important pollinator's for each crop after an hour-long field visit.

Procedure

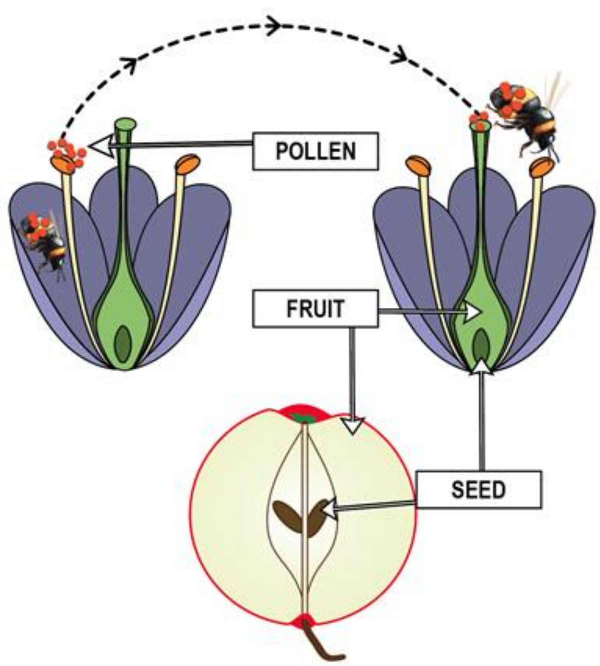
1. The facilitator should first familiarize everyone with the concept of pollination.
2. They should then go into the field and observe some different plants – discuss how each of these plants moves its pollen. Is it wind pollinated (very small boring flowers like grasses, cereals etc.), or insect pollinated (big attractive flowers).
3. The participants should then observe which insects are visiting the different types of flower and watch how they enter and move around the flower.
4. As a group, you can try hand-pollinating a few crop or wild flowers to see how the process works and how much effort it takes. This is the service that pollinators provide us for free. Pumpkins, apples and other squashes are good for demonstrating the movement of pollen between flowers.
5. Participants should report back to the group on their findings, and group discussion around their findings, or questions given below, should be facilitated.
6. Now bring out some common insect specimens (e.g., honeybee), or catch them in the field and bring them back to the classroom. Ask the participants to look carefully at the insect and see where the pollen is being held. Discuss all of the different parts of the body which are adapted for carrying pollen.
7. Bring out a collection of different insect pollinators and show them how many different insects are involved in pollination and show them the range in shapes in sizes. This variation

is very important each pollinator will touch a different part of the flower and together they will increase the chances of successful pollen transfer.

Learning materials:

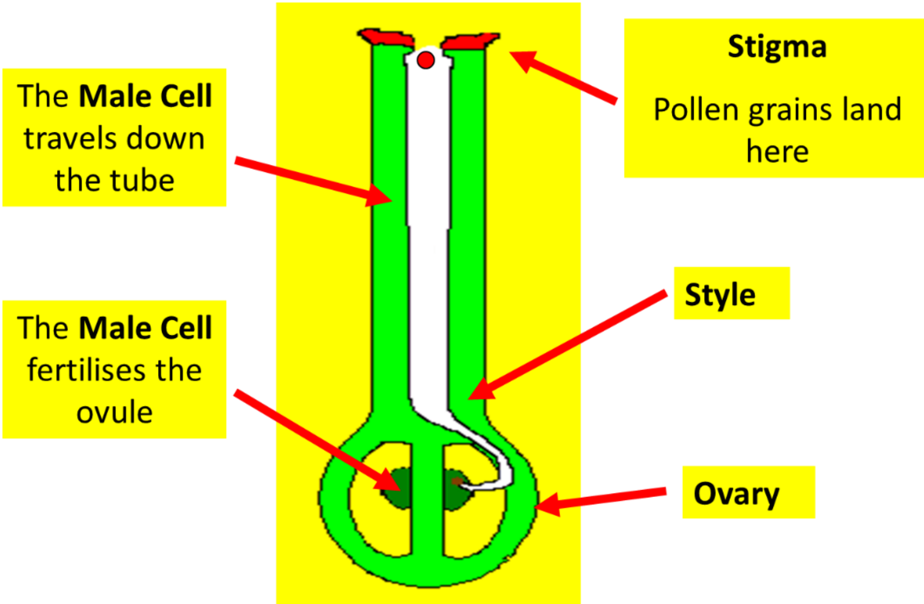
1. What is pollination?

Pollination is the transfer of pollen from the male parts of the flower (the stamens) to the female part of the same or a different flower.



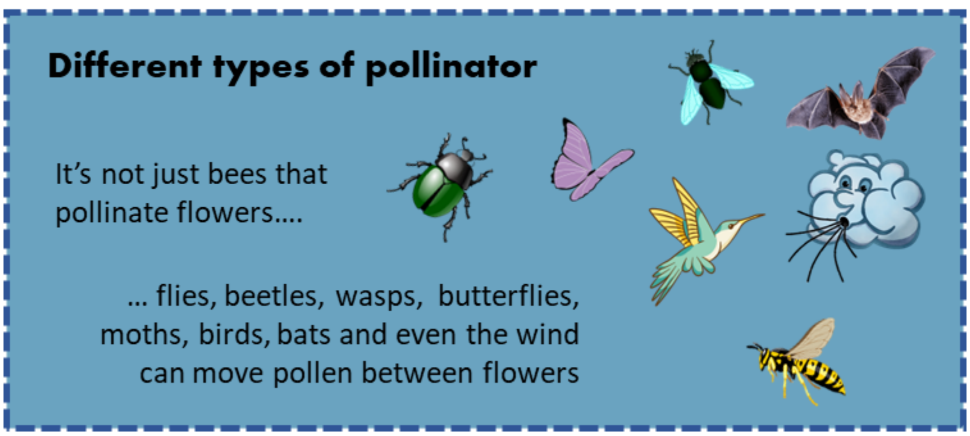
2. Process of fertilization

1. The pollen must be compatible
2. The stigma must recognize the pollen as being from the same or similar plant, and must allow the pollen to fertilize its ovules.
3. The fertilization of the ovule and seed formation will occur.



3. Different methods of pollen transport

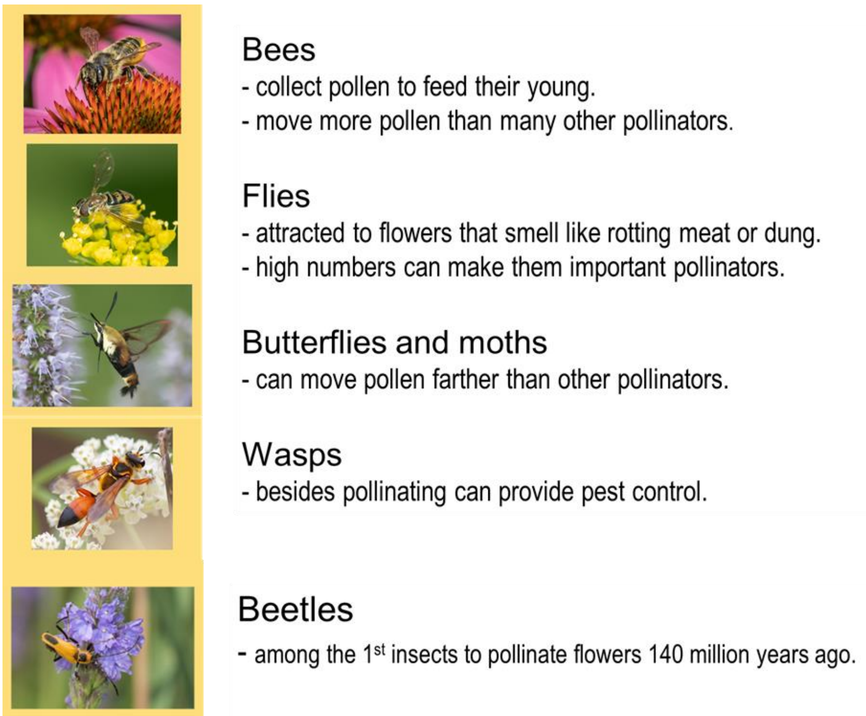
Pollen may be transferred by wind, gravity, water, birds, bats, or insects, depending on the plant. They directly or indirectly ensure the pollination in the flowering plants. In most places however (and for most crops) insects are the most important pollinators.



4. The diversity of insect pollinators

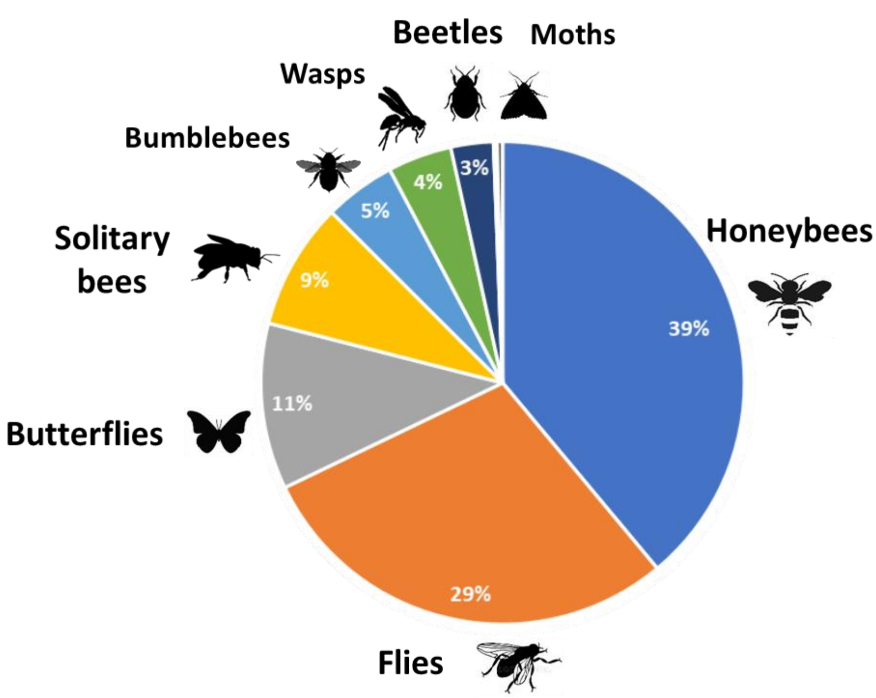
Insect pollinators are insects which visit flowers and transfer pollen from one plant to another. There are thousands of different types of insect pollinator including bees, flies, butterflies, wasps, beetles and ants. The vast majority of insect pollinators in the world are wild, <u>not managed</u> like the honeybee.

Different plants will attract different types of insects, so it is very important to have lots of different insects in your area. The more insects that you have, the higher the chances of all plants being successfully pollinated and the more stable the pollination service will be. The figures below show the variety of different insect pollinators. It is very important to convince participants that there are many more types of pollinator than just the honeybee and ALL of these different pollinators are required to provide a good pollination service. Wild pollinator diversity is therefore essential.

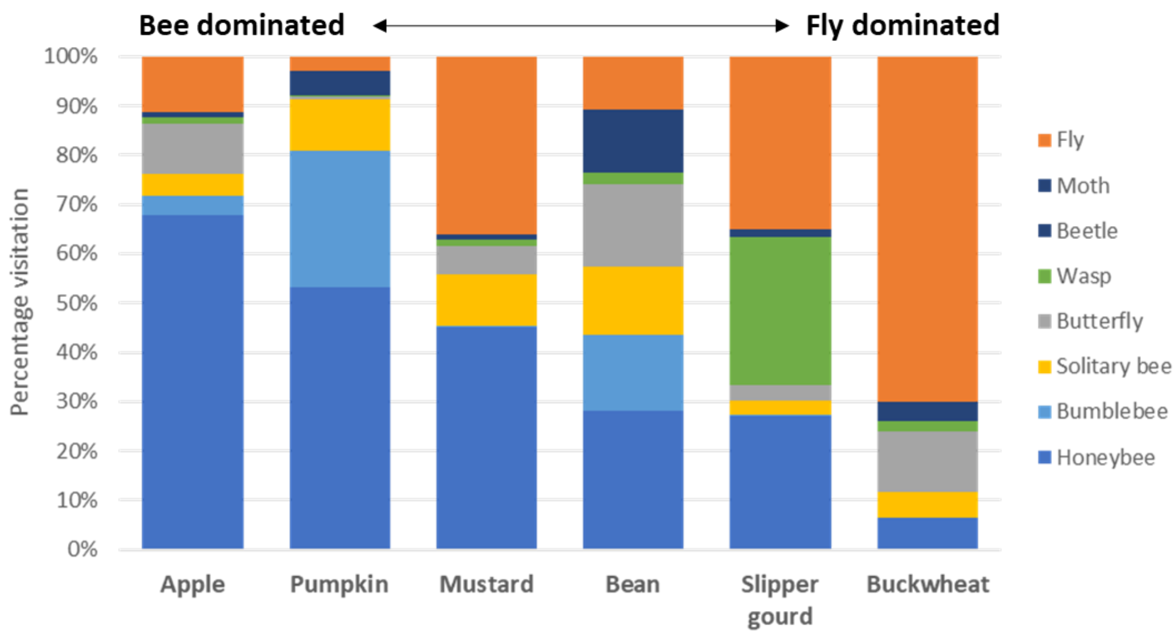


There are 20,000 different bee species in the world – some of these are shown below:

The diversity of insects that visit crops in Jumla:



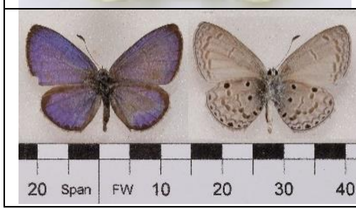
The insect pollinators of six key pollinator-dependent crops in Jumla. To the left are more bee pollinated crops (e.g., apple & pumpkin), whilst to the right are more fly and wasp-pollinated crops (e.g., buckwheat & slipper gourd):



The 15 most important crop pollinators recorded in Jumla:

Image	Insect taxon	Most relevant crops	Notes
	**Asian honeybee** *Apis cerana*	All	Native honeybee that lives in large social colonies in tree or wall cavities. Frequently domesticated in Jumla for honey production.
	**Hoverfly** *Eristalis spp.*	Apple, Mustard, Chili	Large hover flies that often look similar to honeybees. They lay eggs in nutrient-rich water which hatch into 'rat-tailed maggot' larvae with long tails

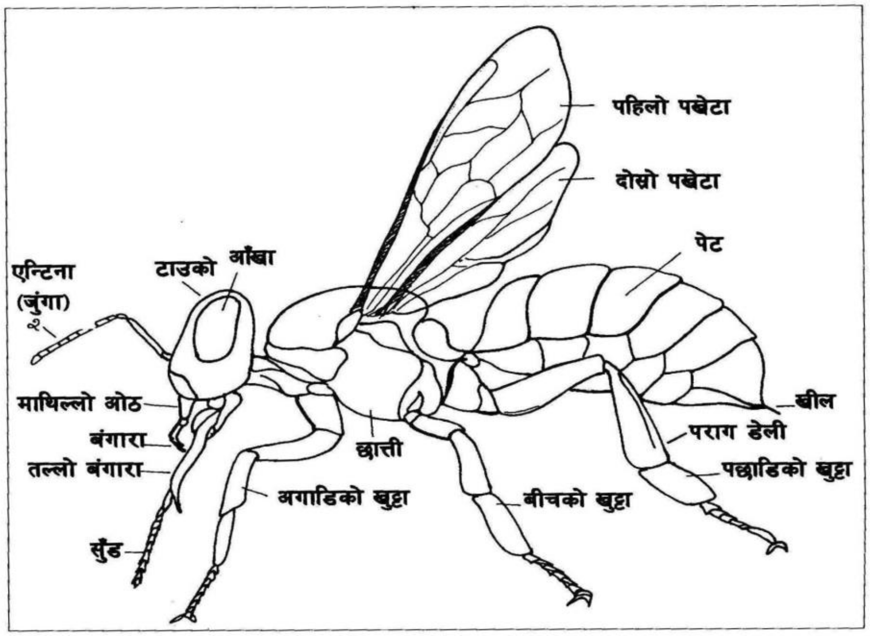
	**Bumblebee** *Bombus spp.*	Pumpkin, apple & bean	Large hairy bees which live in social colonies inside old holes in the ground, trees or walls. Queens overwinter in piles of leaves, soil or sticks
	**Paper wasp** *Polistes spp.*	Slipper gourd	Social wasps which live in nests made from a paper-like substance attached to trees or buildings.
	**Mining bee** *Andrena spp.*	Mustard & chilli	Small (8-17mm) solitary bees which nest in dry sandy soils, often in aggregations. Adults are normally only active for a few weeks
	**Himalayan giant honeybee** *Apis laboriosa*	Bean	The world's largest honeybee, native to the Himalayas, generally occurring above 2500m. Nests in large social colonies on cliff faces.
	**Hoverfly** *Syrphus spp.*	Buckwheat	Smaller hoverfly than Eristalis. Eggs laid onto plants where larvae hatch and feed on aphids before dropping into soil to overwinter as pupae.
	**Sweat bee** *Lasioglossum spp.*	Apple	Small semi-social dark-coloured bees which live in holes in the ground or in rotten logs.
	**Yellow-faced bee** *Hylaeus spp.*	Apple	Small solitary bees which look wasp-like (often yellow and black). They nest in cavities in twigs, straw or plant stems.
	**Sawfly** *Tenthredo spp.*	Slipper gourd	Wasp/bee like insects which are known to visit flowers and pollinate them, but are also predators of other insects.

	**Blow fly** *Lucilia spp.*	Buckwheat & slipper gourd	Common green-coloured fly often seen around dung and animals. The larvae can be parasitic or live in dung.
	**Cabbage white butterfly** *Pieris brassicae*	Apple	Large white butterfly which frequently visits apple flowers in Jumla. Caterpillars feed on brassica plants & may be considered pests.
	**Hedge blue butterfly** *Celastrina lavendularis*	Many crops, particularly buckwheat	A small blue butterfly which regularly visits a range of crops. Caterpillars feed on plants but are unlikely to be pests.

5. Pollinators' morphology and adaptations for carrying pollen

Most pollinators have special adaptations for collecting and carrying pollen. These include hairs on the body, or places on the legs where pollen can be stored. Out of all the insect pollinators, bees are the best adapted for carrying pollen because this is the main food source for their young, so they need to be able to gather and transport it efficiently.

Most of the different types of bees (honeybees, bumblebees and solitary bees) have special places on their back legs or under their arms where they can store large baskets of pollen (see pictures below) and their bodies are also covered in dense hairs which collect pollen. All these morphological features help to carry and transfer the pollen from flower to flower which makes bees some of the best pollinators.



Questions to facilitate understanding:

1. What is pollination?
2. What are the different ways that pollen can move between flowers?
3. What types of insects are important in pollination? (They should know about more than just honeybees)
4. Why are bees (honeybees and wild bees) particularly good pollinators?

Topic 4: The importance of pollinators

- The ‘ecosystem service’ that insect pollinators provide
- Role of pollinators in crop (seed, fruit) production and quality
- The importance of pollinators for human health

Learning goal

To understand the importance of pollinators for the functioning of ecosystems. To understand how much we as humans rely upon pollinators for our livelihoods, crop production and nutrition.

Learning concept

The learners will learn about the role of pollinators on biodiversity maintenance and crop production.

Resources to be used

Important pollinators, cross-pollinating crops, sketch/maps on pollinations related changes, brown papers, sketching pencils, research reports, video, flip chart, marker pens, masking tape.

Duration

The facilitator should spend about 1 hour talking about the importance of pollinators for natural ecosystems, crop production and human health and then another 1-2 hour/s in the field looking at pollinator-dependent crops and discuss how pollinators influence their fruit and seed production.

Procedure

1. The facilitator should familiarize the participants with the importance of pollination for biodiversity, agriculture and human health.
2. As a group, participants should list all of the pollinator dependent crops which they grow and then discuss the consequences (economic, social and nutrition) if they could no longer grow this crop.
3. Go into the field as a group and discuss the process of crop pollination.
4. Apply pollinator exclusion nets to some pollinator-dependent crop branches/plants to test the role of pollination. These can be checked in a few weeks to see the difference in the amount of fruit being set.
5. Group discussion, brain storming, plenary discussion.

Learning materials:

1. The importance of pollinators in natural ecosystems

Animal pollinators (mainly insects) are important for promoting the reproduction (mating and seed production) of around 9 in every 10 wild flowering plants. Without pollinators, most plants would no longer be able to produce seeds and would soon die out. Wild ecosystems like forests, grassland and scrubland would collapse without the ability of plants to reproduce. And all of the animals living in these places and dependent upon the plants for survival would also disappear.

As humans, we are also very reliant on these wild plants and ecosystems for our survival – these environments filter our water, help produce the air we breathe and provide us with most of our medicines, building materials, firewood and other things.

Encourage participants to think about a world without pollinators and what would happen if all the wild plants could no longer produce seeds and started to die out.

2. The importance of pollinators in agriculture

Three out of every four crop plants rely upon animal pollinators for their yield. By moving pollen between crop flowers and ensuring successful fertilization, animal pollinators increase crop yields and also the quality of the fruits and seeds. For many crops, there will be no production of seeds or fruit unless pollination occurs. More seeds will develop when large numbers of pollen grains are transferred. Well pollinated seeds, in turn, stimulate the surrounding ovary tissue to develop larger fruits. In this way, pollination improves both fruit yield and seeds.

Many of the world's most important cash crops (e.g., coffee, cocoa, apples, cardamon, almonds and citrus) benefit from animal pollination in terms of yield and/or quality, providing employment and income for millions of people. The benefits that animal pollinators bring to crop production are estimated to be worth around US $800 billion each year and around US $477 million each year in Nepal.

The images below show what happens to some fruits when they are not successfully pollinated.

Images of good quality (left) and poor quality (right) pollination of strawberries, beans and bitter gourd.

Three out of every **four** crop plants rely on pollination by animals

Nine out of **ten** wild plants rely on pollination by animals
This includes many wild fruits and medicinal plants

The value of pollination to global agriculture is **$800 billion (US)** each year

Not all crops are equally dependent on pollinators, so it is important to know which crops are pollinator dependent and how much their yields would reduce in the absence of pollinators. The table below shows the 10 most important pollinator dependent crops in Jumla; the percentage pollinator dependence tells us how much the yield of that crop would decline if there were no insect pollinators to move its pollen.

Image	Names	Pollinator dependence	Notes on importance
	**Apple** *Malus domestica* Shyau (स्याऊ)	65%	Most important cash crop in Jumla & major income source for many farming households
	**Jumli bean** *Phaseolus vulgaris* Jumli simi (जुम्ली सिमी)	25%	Staple legume crop in Jumla and major protein source, especially throughout the winter.
	**Pumpkin** Cucurbita maxima Kaddu (कद्दू)	95%	Widely grown vegetable – important source of micronutrients, particularly vitamin A and folate.
	**Slipper gourd** Cyclanthera pedata Chuche karela / Barela (चुच्चे करेला/ बरेला)	95%	Widely grown vegetable – important source of micronutrients, especially during winter.

	**Buckwheat** Fagopyrum tataricum Tite phaaper (तीते फापर)	65%	Nutritious staple cereal crop in Jumla. Production declining, but still widely consumed.
	**Mustard** Brassica alba Tori (तोरी)	25%	Important oil seed crop widely grown in Jumla. Mustard leaves also a nutritious widely eaten food item.
	**Chilli** Capsicum sp. Khursani (खुर्सानि)	75%	Very widely and frequently eaten. High in micronutrients
	**Soybean** Glycine max Bhatta (Kalo & Seto) भट्ट (कालो र सेतो)	25%	Widely eaten pulse and an important source of protein.
	**Cucumber** Cucumis sativus Kakhara (काँक्रा)	65%	Nutritious vegetable, frequently grown in lower areas
	**Peach** Prunus persica Aaru (आरु)	65%	Widely grown nutritious fruit. Most commonly grown for household consumption rather than sale.

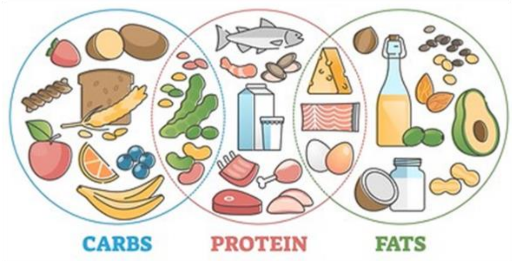
3. The importance of pollinators to human health

As humans, we get most of our macronutrients (carbohydrates, protein and fats) from animal products and from staple grain crops like rice, wheat and maize which do not rely upon animal pollinators for their yield. However, in addition to these macro nutrients, humans also require a whole range of other nutrients like vitamins and minerals which are called micronutrients. Many of these vitamins and minerals are found in fruits, vegetables, nuts and seeds which are normally very pollinator dependent. If pollinators disappeared, it would be easy to get enough calories, but our consumption of vitamins and minerals would dramatically decrease and this would have very severe impacts on our health.

Macronutrients

Required in large amounts for energy and growth

- Carbohydrates
- Proteins
- Fats



Micronutrients

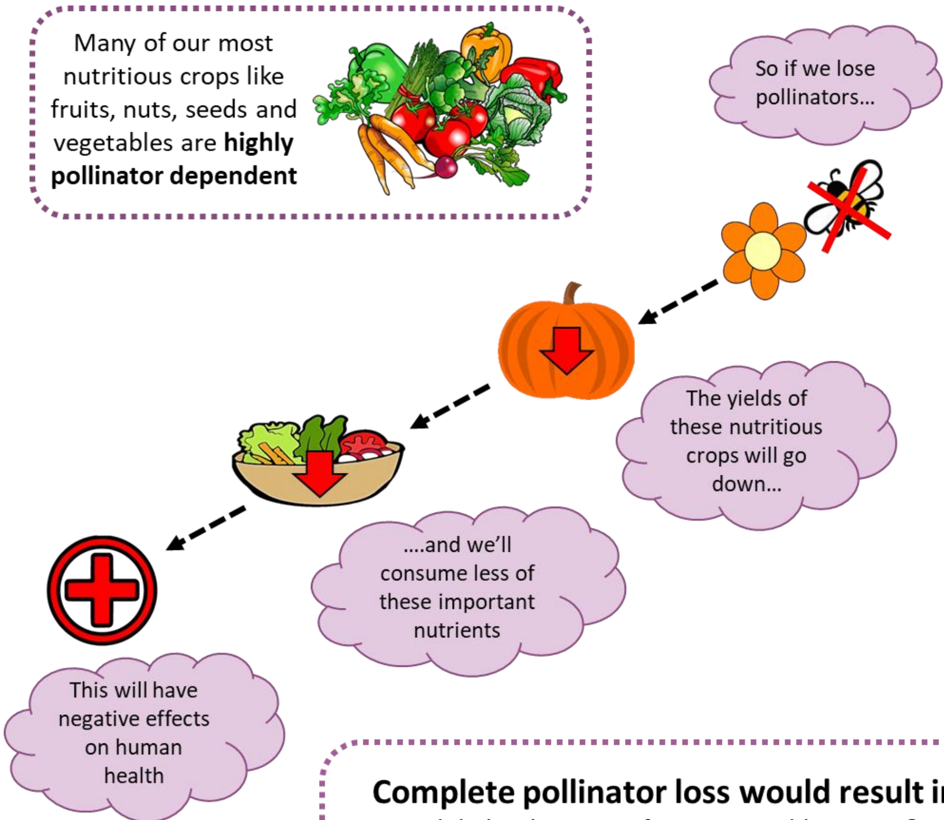
Also known as vitamins and minerals

Required in small amounts but are crucial for healthy development, disease prevention, and wellbeing

Half of all children suffer from some micronutrient deficiency

Examples are:

- Iron
- Vitamin A
- Folate
- Vitamin D
- Zinc
- Iodine



Complete pollinator loss would result in:

A 20% global reduction in fruits, vegetables, nuts & seeds
An extra **71 million** people deficient in **Vitamin A**
An extra **173 million** people deficient in **folate**
An extra **1.42 million deaths** each year

Smallholder farmers in developing countries are likely to be most affected

They are highly reliant on nutrients from pollinator-dependent crops…

And have very little flexibility to change farming practices or obtain food from elsewhere

Questions to facilitate understanding

1. What would happen to wild plants if there were no pollinators?
2. How would this affect wild animals, livestock and people? List all of the different things you would lose.
3. Make a list of all the crops you grow that depend on pollinators
4. What would happen if the yield of these crops reduced? Discuss the changes in your income and your diets if these crop yields reduced.

Topic 5: The ecology and lifecycle of insect pollinators

- Overview of the different insect pollinator lifecycles
- Food requirements of different pollinators
- Nesting/reproduction requirements of different pollinators

Learning goal
To understand the ecological requirements of insect pollinators and appreciate the variety of different life cycles and food and nesting requirements.

Learning concept
The learners will learn about the lifecycles and ecological requirements of insect pollinators

Resources to be used
Flip chart, marker pens, pollinator nesting materials (hollow stems, dead wood etc.), video

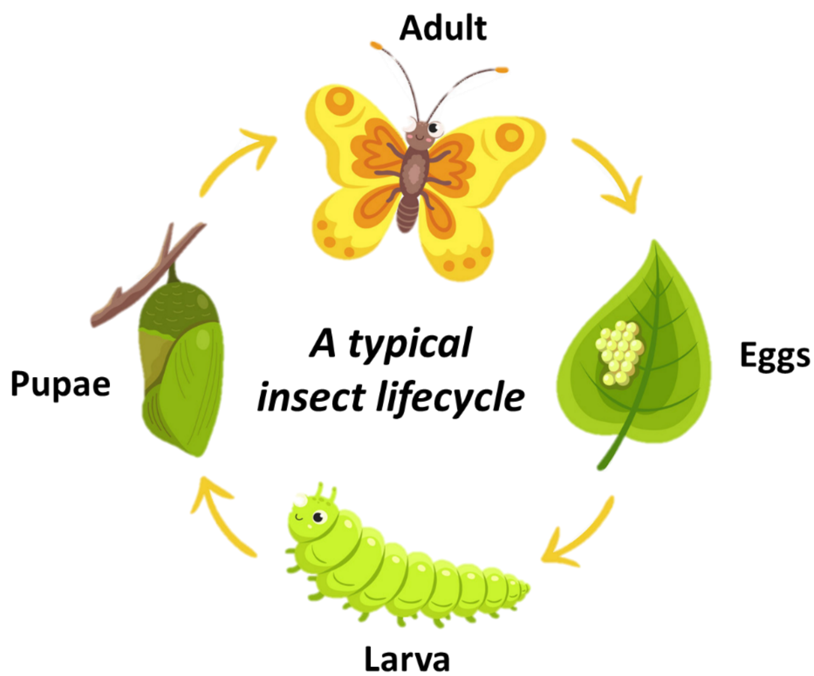
Duration
The facilitator should spend about 1 hour talking about the lifecycle of pollinators and their diverse ecological requirements and then go into the field for 1 hour to identify suitable habitat features for pollinators.

Procedure
1. The facilitator should familiarize the participants with the life cycles of different pollinator groups using the information materials provided below.
2. Facilitators should outline the basic ecological requirements of each pollinator group
3. They should hand around some examples of pollinator nesting materials and show pictures of pollinator nesting sites.
4. Go into the field as a group and look for suitable pollinator habitat features such as bare slopes, hollow stems, dead wood, pools of water, flower-rich patches and shrubs etc. Try to identify bee nesting holes and look for the larvae of hoverflies in ponds/ditches, or feeding on aphids.
5. Group discussion, brain storming, plenary discussion.

Learning materials:

1. General insect pollinator lifecycles

Insects are different from most other animals as they have quite complex lifecycles with lots of different stages. They generally begin as an egg, then hatch into a larva (like a small worm) which eats and eats and then develops into a pupa which eventually turns into the adult form of the insect. This lifecycle with lots of different stages means that insects need lots of different habitat features.



Even between the different groups of insect pollinators (e.g., bees, flies, butterflies, wasps etc.), each one has a slightly different lifecycle, and it is important to understand something about these lifecycles if we are going to manage them successfully.

2. Bees - lifecycle and ecological requirements

Bees are unique in that they require pollen and nectar both as adults and as larvae. This means that they are extra-reliant on flowers and it also makes them very good pollinators because they are specially adapted for carrying pollen back to their nest. It is important that bees have a range of different flowers available to them as each type of flower contains different nutrients and they need a whole range of nutrients to stay healthy.

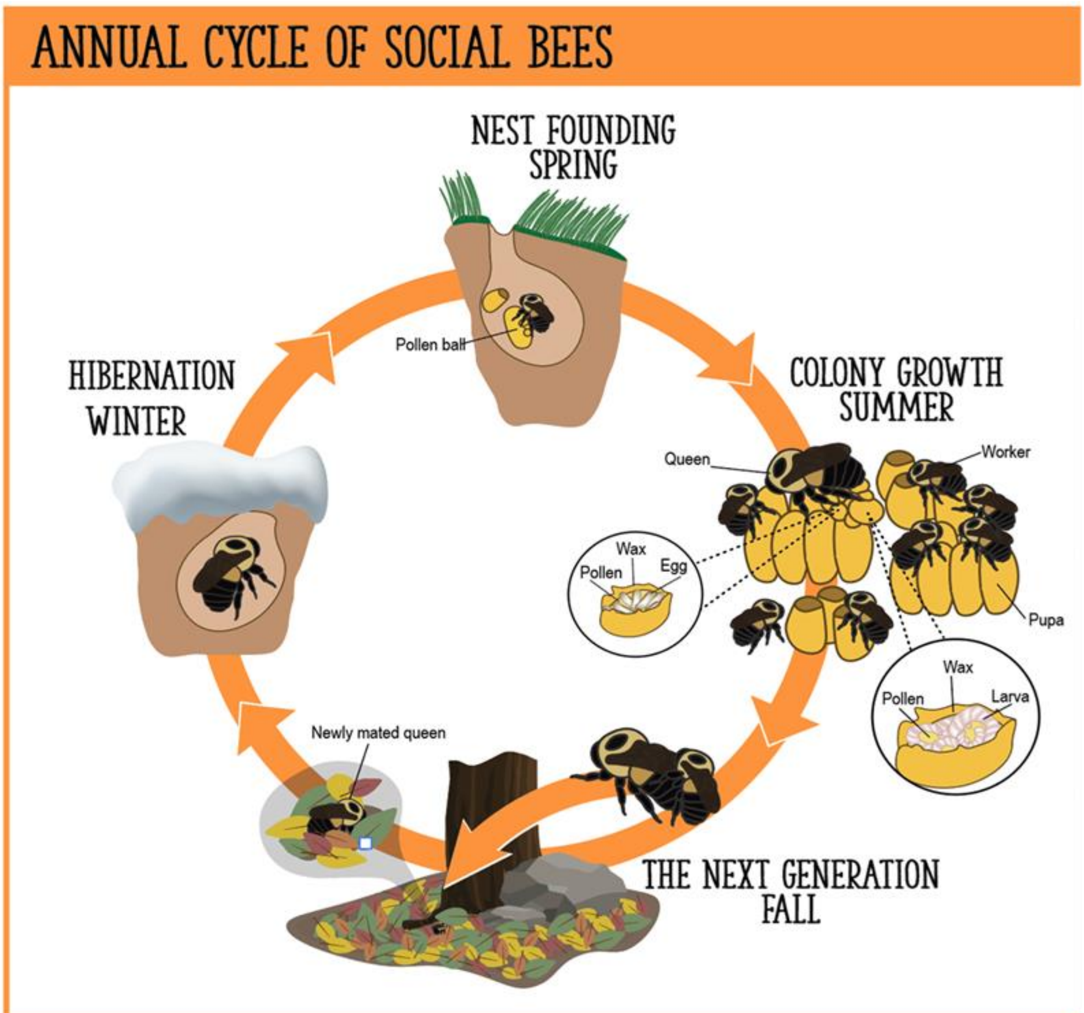
In addition to a rich supply of flowers, bees also require suitable nesting sites to raise their young. These nesting requirements may include dead wood, cavities in trees, holes in the ground, hollow stems, bare earth, patches of bushes or loose sand. Different bee species have different nesting requirements, so it is very important to maintain a range of these resources. Bees are known as 'central place foragers' because they have a nest which they must return to after each foraging trip. This means that bees need everything for their survival (food, water, shelter, nesting materials etc.) available within a short flight of the nest. The largest bees like bumblebees and honeybees can forage around 1 km from the nest if needed, but many of the smaller bees can only travel a maximum of 100-500 meters, so if you are aiming to maximize pollination services on your farm, it is important that all of the required habitat features are available within a few hundred meters of the field.

There are two main groups of bees:

1) Social bees which nest in large, shared colonies and work as a team to collect food and raise young. Examples of these are honeybees and bumblebees.

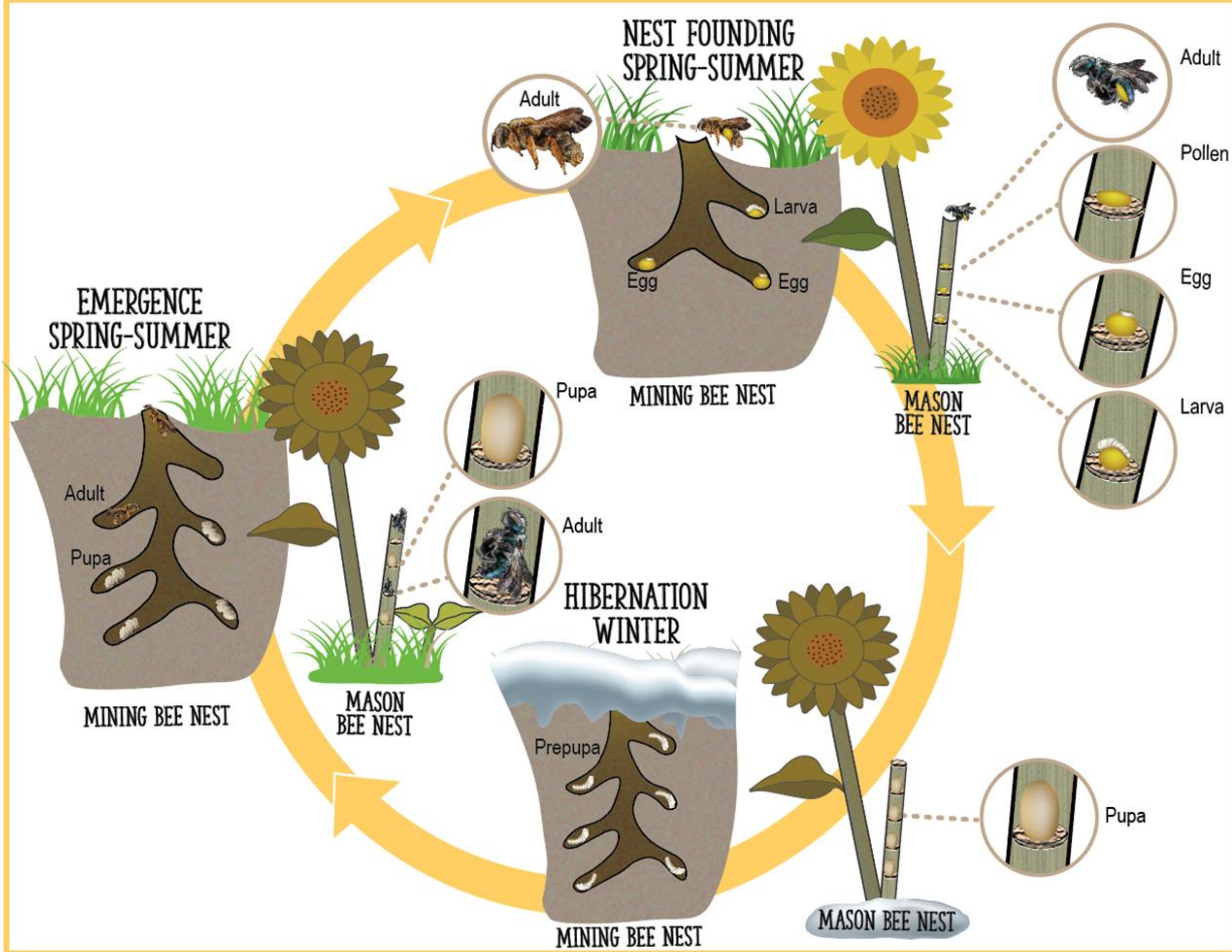
2) Solitary bees which nest individually in small holes or burrows and raise young on their own. Sometimes these bees will nest near to each other in clusters, but they do not work together – they are each responsible for raising their own young. There are many more types of solitary bees than social bees and they have a very important role in pollination.

The lifecycles and nesting requirements of these two groups of bees are quite different and are outlined in the diagrams below.

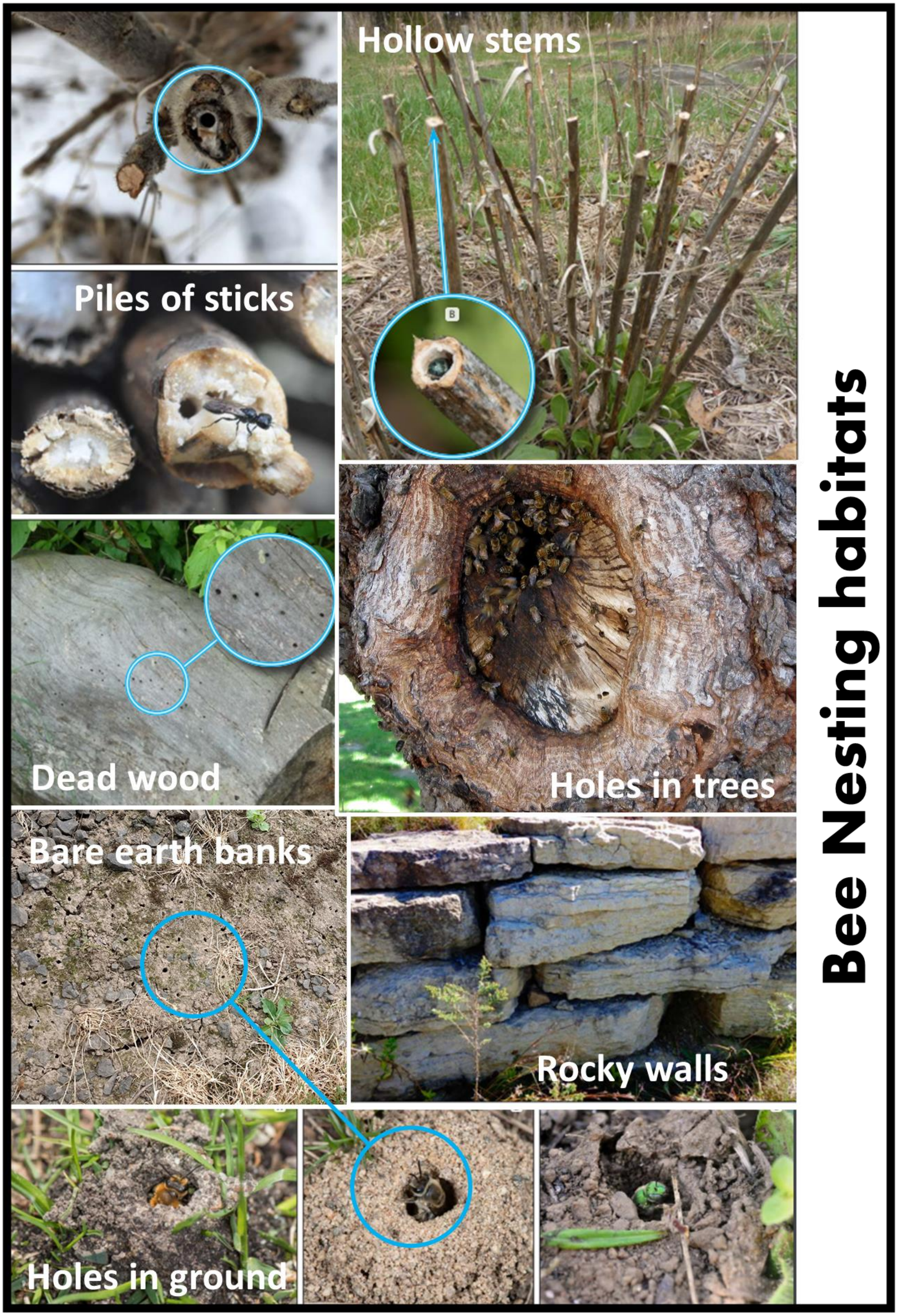


- The mother bee (queen) stays in nest, cooperates with daughters or sisters & raises many young bees
- Common social bees include bumble bees, honeybees, some sweat bees and carpenter bees.

ANNUAL CYCLE OF SOLITARY BEES



- Mother bee makes nest, gathers food, lays eggs
- Baby bees grow on their own

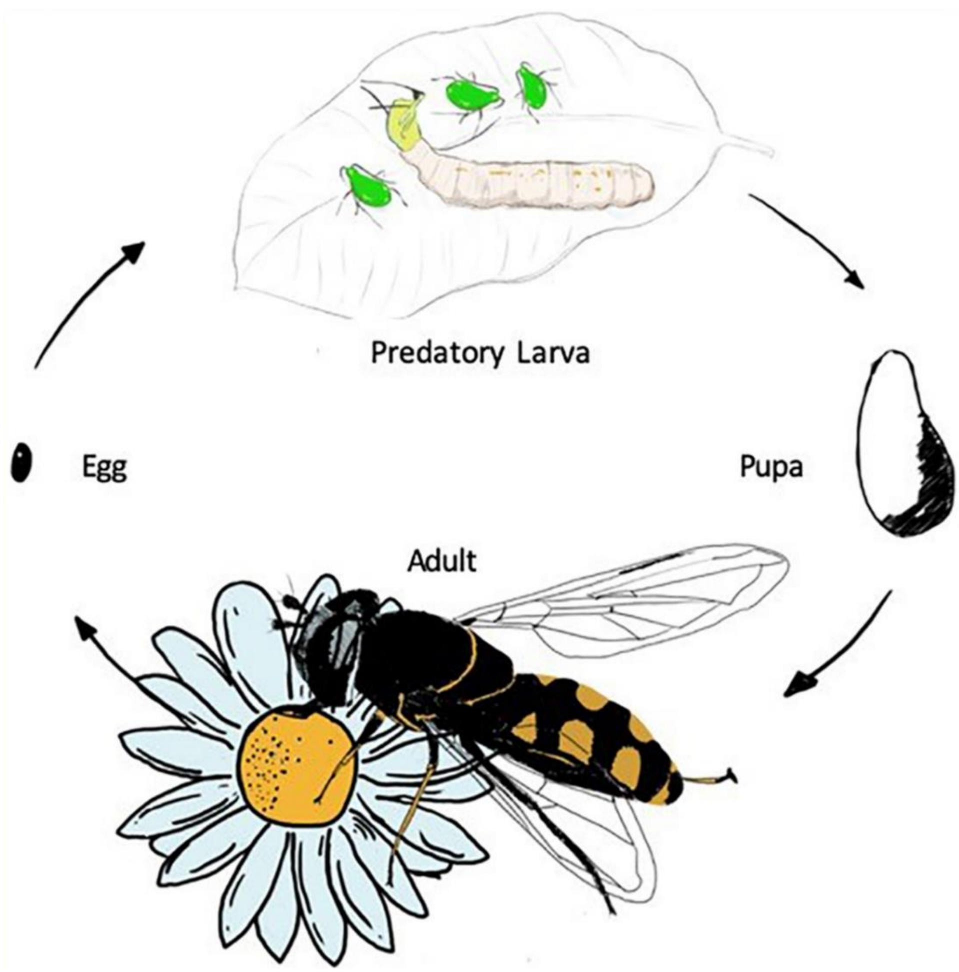

Bee Nesting habitats
Hollow stems
Piles of sticks
Dead wood
Holes in trees
Bare earth banks
Rocky walls
Holes in ground

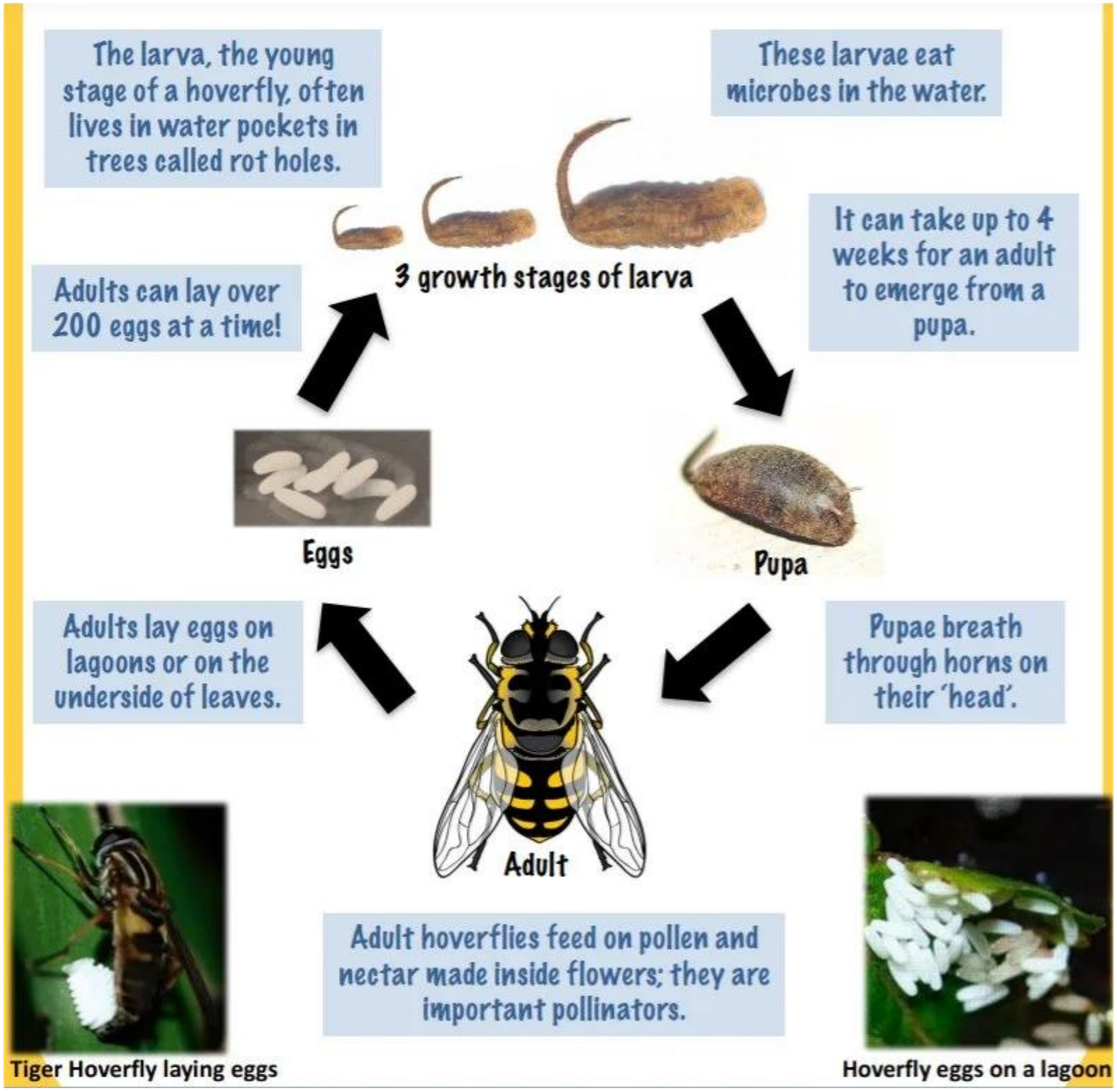
3. Flies - lifecycle and ecological requirements

There are many different types of flies and not all of them are pollinators. The most important group of fly pollinators are the hoverflies (Syrphids), though other flies such as blow flies (*Lucilia*) can be important too.

Like other insects, flies have an egg, larval, pupal and adult stage of their lifecycle. But unlike bees, it is normally only the adult flies that feed on pollen and nectar. Flies do not have a nest that they return to, so they are free to move around the landscape in a fairly random way. However, their larvae have quite specific habitat requirements which must be met if they are to survive in the landscape.

The larvae of many fly species are predators, feeding on insects such as aphids and scales, thus providing biological control of pests. Others feed on dung or rotting plant material, so help to break down organic matter, thereby releasing nutrients back into your soil. Others live in stagnant water like ponds and ditches.

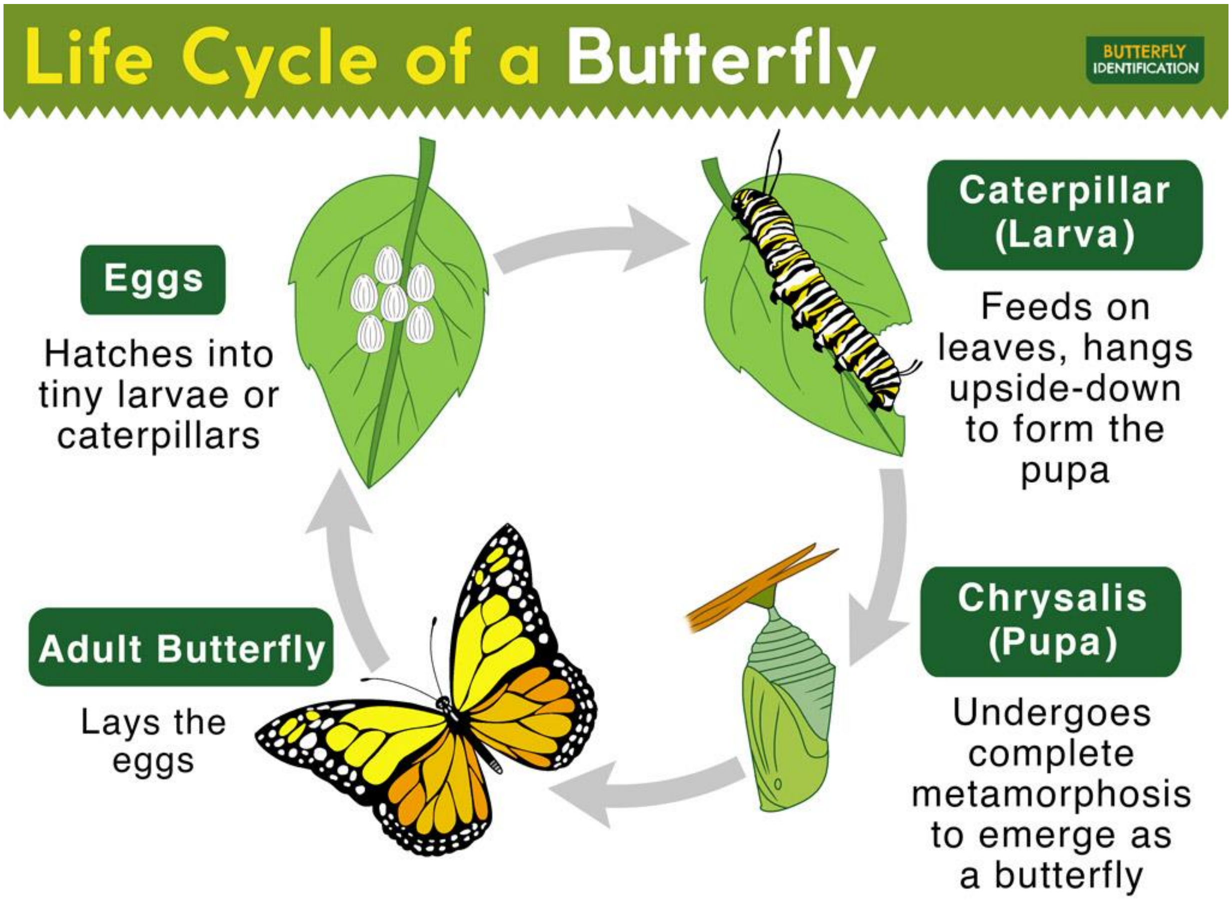




4. Butterflies & moths - lifecycle and ecological requirements

Like other insects, there are four stages in the lifecycle of butterflies and moths: egg, larva, pupa, and adult. Eggs are laid on plants by the adult female butterfly. These plants will then become the food for the hatching caterpillars. Females lay a lot of eggs at once so that at least some of them survive. Butterfly eggs can be very small.

The next stage is the larva which is also called a caterpillar. The job of the caterpillar is to eat lots of plant material and grow quickly. Food eaten at this time is stored and used later as an adult. When the caterpillar is fully grown and stops eating, it becomes a pupa. Depending on the species, the pupa may suspended under a branch, hidden in leaves or buried underground. The pupa of many moths is protected inside a cocoon of silk. Finally, the pupa will develop into an adult butterfly or moth which emerges and flies around to mate and lay more eggs. To keep up their energy, most butterflies will visit flowers to get sugary nectar – this is how they act as pollinators.



Questions to facilitate understanding

1. Draw the four main stages in the insect lifecycle
2. What are the two main groups of bees and how are they different from each other?
3. Aside from flowers, what is the other main habitat requirement for bees?
4. What do hoverflies feed on as larvae?
5. Identify 5 features of the environment that make good nesting sites for bees.
6. What benefits to flies bring to agriculture?

Topic 6: Pollinator declines

- The decline of pollinators around the world, including Nepal
- Reasons for decline
- Consequences of decline
- What can we do about it?

Learning goal
To understand that pollinators are declining in many places and that the primary cause of these declines is agricultural intensification and unsustainable farming practices. To understand how agriculture and other human pressures affect the lifecycles of pollinators.

Learning concept
The learners will learn about the drivers behind pollinator decline and how this influences pollinators.

Duration
The facilitator should spend about 1 hour talking about the declines of pollinators and then go into the field to spend 1 hour discussing why farmland and intensive farming practices can be harmful for pollinators.

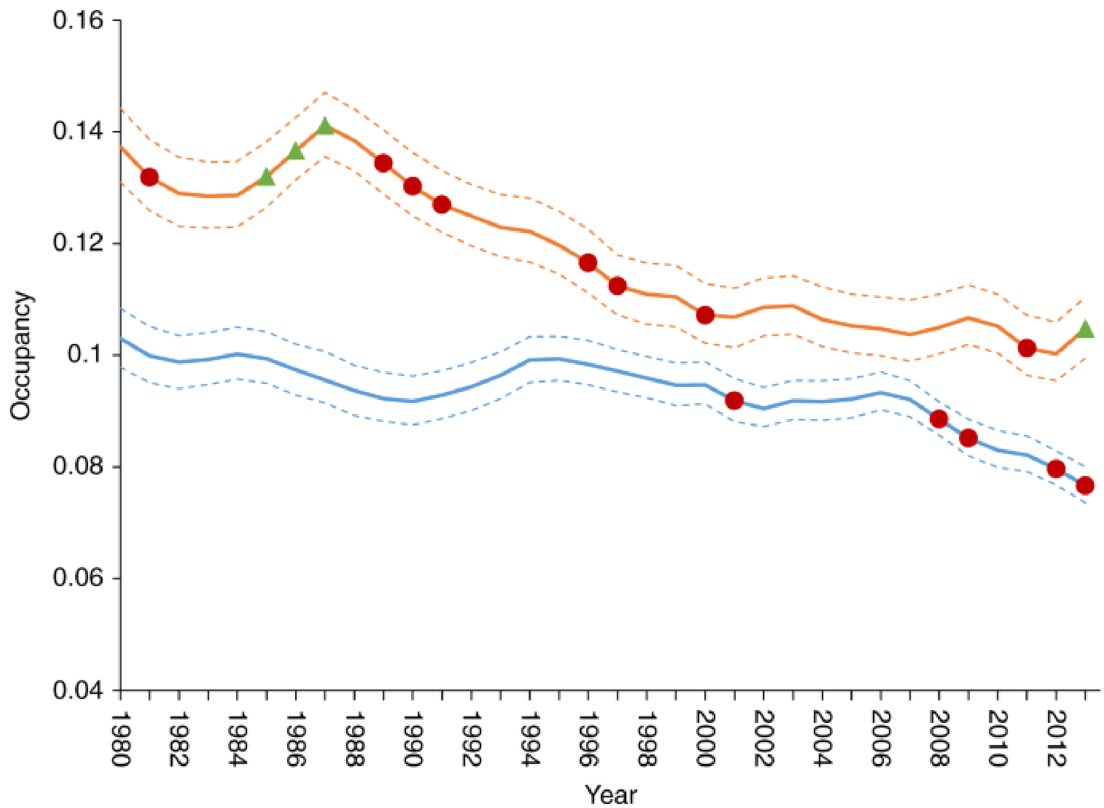
Procedure
1. The facilitator should familiarize the participants with the extent of pollinator declines and give some specific examples from around the world and in Nepal
2. As a group, participants should discuss why they think pollinators are declining – what do they think has changed that would make pollinators decline?
3. Go into the field as a group and discuss the features of farmland that might be challenging for pollinators. Compare some healthy areas of natural habitat with areas of intensive farmland and encourage them to discuss the differences.
4. Group discussion, brain storming, plenary discussion.

Learning materials:

1. Pollinator declines around the world

Europe and North America are the only places in the world where we have been monitoring pollinators for long enough to know that they are declining. From these records, we can see that wild pollinators are in decline. Local studies in other parts of the world, including Asia, Africa and South America suggest that pollinators are also declining in these places.

Examples of declines in wild bees (blue) and hoverflies (orange) in Britain from 1980 – 2014. From: Powney et al. 2019.



2. Pollinator declines in Nepal

In the Hindu-Kush Himalayan (HKH) region, which includes Nepal, there is evidence of declines in pollinator numbers reported from apple farming areas including Jumla District in Nepal (Partap 2012). Surveys in these areas have revealed that inadequate pollination has severely affected apple production and yields and quality of fruit have declined accordingly.

The decline in pollinator abundance and diversity presents a serious threat to agricultural production and the maintenance of biodiversity in Nepal. Possibly the worst affected crops are cash crops such as fruit, oilseeds, and off-seasonal vegetables, on which farmers rely for cash income. The best indicator of the decline in natural insect pollinators is the decrease in crop yields and quality, despite adequate agronomic inputs and intensive efforts.

3. Reasons for decline

There are many reasons why pollinators are declining across Nepal and the rest of the world and all of these reasons are primarily driven by humans, particularly through the expansion and intensification of agriculture. These human-driven actions affect pollinators in four main ways:

1) Reducing the food supplies (number of flowers) for pollinators;
2) Reducing the availability of nesting sites for pollinators

3) Increasing exposure to harmful chemicals such as pesticides
4) Increasing the spread of diseases which affect pollinators

Below are some of the key drivers of pollinator decline in Nepal, as outlined by Partap 2012:

Habitat loss

The continuing increase in farmland area, at the expense of forests and grasslands, leads to the loss of nesting sites and food resources for pollinators. For example, in the past decade alone, the area under apple cultivation in the countries of the HKH region increased by about 60%, from 367,000 ha in 1998 to 594,000 ha in 2008. The same is true for vegetables and other crops. One of the reasons for this expansion is that climate change is enhancing the opportunities for cash crop farming in high mountain areas that used to be permanent grasslands until a decade ago.

The negative impact of agricultural intensification on the abundance of natural insect pollinators has been demonstrated in numerous studies from around the world. Farmers' surveys in the countries of the HKH region reveal that both the diversity of insect pollinators and their numbers on crops have seriously declined in areas where cash crop farming has increased.

Increase in monocultures

Increasing cash crop farming based on monocultures has contributed to a reduction in the diversity of plants that provide food for pollinators. In the past, mountain farmers grew a variety of crops, which bloomed at different times of the year and provided food for a number of natural insect pollinators. The transformation of agriculture from traditional mixed crop farming to high value cash crop farming in recent years has led to an increase in monocrop agriculture, reducing the food sources for natural insect pollinators. Reports from several mountain areas indicate that mountain farmers are switching on a large scale to the cultivation of cash income-generating fruit crops and off-seasonal vegetables.

Pesticides

The problem with cash crop farming is that farmers use insecticides and pesticides indiscriminately, contributing to the decline in natural insect pollinators. Studies carried out in parts of the HKH region have revealed very low pollinator numbers in apple farming areas because of the excessive and indiscriminate use of pesticides on apples and other cash crops. Some apple farmers spray different pesticides (including insecticides) as many as 10 times in a season, and in Himachal Pradesh almost 30% of farmers spray during the flowering period. Agricultural pesticides kill not only the wild foraging insects, they also kill honeybee colonies in surrounding areas and reduce the number of wild flowers for the pollinators to feed on.

Forest fires

Forests provide habitats for nesting and hibernation and food sources for a variety of pollinator species. Studies have revealed that there are more insect pollinators in apple orchards situated near forests than those that are far from forests (Sharma and Gupta 2010). Therefore, a decline in forest area either by its conversion to farmland or destruction in other ways (such as forest fires) has a negative impact on pollinator abundance. Forest fires in summer, largely engineered by farmers for fresh growth of grass on forest floors, is a key factor affecting pollinator populations in some areas. Forest fires not only destroy the nesting places and food sources of pollinators, they also kill pollinators hibernating or nesting in the area. Using fire to clear forests for agriculture is a common practice among communities in the northeastern Himalayas, including in Nepal. It is also common practice for farmers in the Himalayan region to use fire in the fields and grasslands to control weeds and to improve the quality of grass the following year. The removal of weeds reduces the diversity of food sources available to pollinating insects.

Overgrazing

Excessive populations of grazing livestock reduce the number of wildflowers in grasslands and therefore reduce food supplies for pollinators. If pollinators can't find enough flowers to gain the energy they need and feed their young, they won't be able to survive.

Exotic honeybees

The introduction of exotic honeybee species can negatively affect populations of native bee species. This may be because of competition for food, the transfer of pests and diseases from one species to another, or economic preference for exotic species. The introduction of *Apis mellifera* to increase honey production has led to a decline in beekeeping with indigenous *Apis cerana* in several countries of the HKH region.

Climate change and other factors

Climate change may also be affecting insect numbers, as changes in temperature and rainfall can both impact the survival of pollinators. In many parts of the world, pollinators have been recorded moving up to higher altitudes to seek cooler temperatures, whilst in other places, the earlier arrival of spring or the rainy season has disrupted the natural lifecycles of pollinators causing them to change their emergence and activity times. In some cases, pollinators are no longer active at the same time as their preferred food plants.

Pollinators are declining across much of the world

Why are they declining?

Habitat loss

Land cleared for farming means there is **less food** from flowers **and fewer places to nest** for pollinators

Climate change

Changing seasons **disrupt the natural lifecycles** of pollinators.
Increasing temperatures force them to **move home**

Pesticides

Pesticides are **poisons** to insects - as well as killing crop pests, they also **kill pollinators**

Parasites & disease

Humans have spread many **new parasites & diseases** around the world – these are affecting pollinators

Most of these threats are driven by the **expansion and intensification of agriculture…**

4. What can we do to reverse pollinator declines?

Although agriculture is a major driver of pollinator declines, it is possible to make some simple changes to our agricultural practices to ensure that pollinators are well supported on farmland. This not only benefits pollinator and plant biodiversity, it will also enhance the pollination services on farmland, therefore increasing crop yields.

The simplest and most effective way to enhance pollination services of both wild and managed pollinators is to understand their basic ecological requirements and then adjust farming practices to ensure these requirements are met.

Pollinating insects (including managed honeybees) have three fundamental ecological requirements:

1) Sufficient food in the form of pollen and nectar from flowering plants

2) Suitable environments for nesting, raising young and sheltering from the weather and predators

3) Freedom from harmful agents such as pests, disease and toxic chemicals such as pesticides.

Grow Pollinator-Friendly Flowers
Flowers provide the nectar and pollen that pollinators feed on. They need lots of these foods throughout the year. Growing the right flowers, shrubs, and trees with overlapping flowering times will support pollinators throughout the year.

Provide Nest Sites
It is important to support all pollinator life stages, including eggs and larvae. For bees, you can leave patches of bare ground and brush piles or install bee hotels & hives. Other pollinators may need water, or specific plants for their larvae to feed on

Avoid Pesticides
Pesticides, especially insecticides, are harmful to pollinators. Herbicides reduce food sources by removing flowers from the landscape. Fungicides can also have negative effects on bees. The good news is that there are alternatives.

Questions to facilitate understanding

1. Why are pollinators declining? List and discuss the major drivers of decline.
2. Which of these drivers of decline have you experienced in your area?
3. Have you noticed any changes in the number of flying insects during your lifetime?
4. What would you change about your farming practices to help pollinators?

Topic 7: Managing pollination services

- The benefits of managing pollination services
- Improving food resources (flowers) for pollinators
- Improving nesting sites for pollinators
- Reducing risk factors for pollinators
- Specific practices for managing apple pollination

Learning goal

To understand what we can do as farmers to increase the abundance and diversity of insect pollinators to enhance pollination services.

Learning concept

The participants will learn about the three main things we can do to support pollinators on farmland (increase food supplies, increase nesting sites and reduce risk factors) and how each of these can be achieved.

Duration

The facilitator should spend about 2 hours talking about the different management options for supporting pollinators on farmland. Participants should then work as a group for 1 hour to plan (draw) the perfect pollinator-friendly farm and list all the changes they could make to their farm. Then go out into the field for 1 hour and discuss the things you could change about the farmland to make it better for pollinators. Solitary bee nest building exercise will take 1 hour. Final group discussion 1 hour.

Procedure

1. The facilitator should familiarize the participants with the management options for supporting pollinators on farmland
2. As a group, participants should plan a perfect pollinator-friendly farm
3. Go into the field as a group and discuss the features of farmland that are good for pollinators and the additional things you could add to make it even better
4. Solitary bee nest-building exercise. Hoverfly lagoon building exercise
5. Final group discussion where each farmer makes a list of things they will do to make their farm better for pollinators.

Learning materials:

1. Overview of pollination management

Pollination is one of the cheapest and easiest agricultural inputs to manage and can be improved over very short time periods (i.e., within one year). Pollination services in agriculture have traditionally been managed through the addition of honeybee hives to farmland. Whilst this often provides a highly effective short-term improvement in pollination services, it does not necessarily provide a sustainable long-term solution and it puts farmers at great risk of honeybee losses, for example through disease. To ensure against honeybee losses and maintain stable pollination services in the long-term, it is necessary to promote wild pollinators too. An abundant and diverse wild pollinator community not only provides insurance against honeybee declines (which appear to be accelerating in this region), it also provides a far more effective pollination service, allowing farmers to achieve greater yields. This is because different pollinators (e.g., wild bees, flies, wasps etc.) are active at different times of day and different times of year and prefer different plants because of their different body shapes and sizes. This ensures a far more complete pollination service than just one single species (e.g., the domesticated honeybee) can ever provide alone.

The simplest and most effective way to enhance pollination services of both wild and managed pollinators is to understand their basic ecological requirements and then adjust farming practices to ensure these requirements are met.

Pollinating insects (including managed honeybees) have three fundamental ecological requirements:

1) Sufficient food in the form of pollen and nectar from flowering plants

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Grow Pollinator-Friendly Flowers
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Provide Nest Sites
It is important to support all pollinator life stages, including eggs and larvae. For bees, you can leave patches of bare ground and brush piles or install bee hotels & hives. Other pollinators may need water, or specific plants for their larvae to feed on

Avoid Pesticides
Pesticides, especially insecticides, are harmful to pollinators. Herbicides reduce food sources by removing flowers from the landscape. Fungicides can also have negative effects on bees. The good news is that there are alternatives.

2. Increasing pollinator food supplies

This is widely considered to be the most effective way to increase pollinator abundance and diversity on farmland and its effectiveness has been demonstrated in many parts of the world (Blaauw & Isaacs 2014; Carvell *et al.* 2017). Below are a number of management actions that should be taken on the demonstration farms to increase food supplies for pollinators.

Plant flowering field margins

Flowering field margins are strips or blocks of dense flowers that are planted alongside crop fields. They are commonly used in Europe and North America to increase pollinator abundance and diversity and have been shown to be highly effective in boosting pollinator populations (Carvell *et al.* 2017). Flowering field margins have been shown to increase the yields of pollinator dependent crops nearby (Blaauw & Isaacs 2014) and this benefit can cover the costs of the land sacrificed to grow them. These areas of dense flowers can be grown underneath apple orchards or alongside flowering crops such as beans, mustard or pumpkin, to increase their pollination services. Choosing the right flowers is very important though and not all plants are equal to pollinators - some are particularly rich in nutritious nectar and pollen or provide food at a particularly important time of year (e.g., early spring).

See the **Demonstration Farm Manual** for a list of suitable pollinator forage plants in Jumla.

Plant a diversity of flowering crops

Pollinators need a continuous supply of food during their activity period (March – November for most pollinators and even longer for honeybees). Gaps in food supply are common on farmland and can majorly impact pollinator populations, reducing their abundance and the provision of pollination services. One of the best ways to ensure a continuous supply of food for pollinators is to grow crops that flower at different times of year so that pollinators can move from one crop to the other when flowering ends. For example, peach trees flower very early in the year, so could be grown near apples to provide pollinators with a good source of food prior to apple flowering. Pollinators can then move onto other later-flowering crops such as potato, mustard, buckwheat and vegetables once apple flowering has ended. Note that it is also important to have lots of wild plants flowering at the same time as these crops because pollinators need a diverse diet.

See the **Demonstration Farm Manual** for a list of sequentially-flowering crops to support pollinators in Jumla.

Grow hedgerows

Hedgerows are strips of bushes and small trees which are traditionally used as field boundaries or livestock enclosures. They are not very common in Nepal but could provide enormous benefits to pollinators (and other biodiversity) if used more widely. Hedgerows typically provide a rich supply of flowers as well as secure nesting sites for many pollinators and have been shown to enhance pollinator abundance (Morandin & Kremen 2013) and the abundance of natural pest enemies, providing a dual benefit to agriculture (Morandin *et al.* 2016).

See the **Demonstration Farm Manual** for a list of suitable plants to use in hedgerows.

Hedgerows – *bushy field borders with an abundant supply of food and nesting sites for pollinators and natural pest predators*

Use these plants as the structure of the hedge

Prinsepia utilis
Dhatelo (ढटेलो)

Cotoneaster microphylla
Ghangaru (घंगेरू)

Rosa sericea
Karausi ko phul (करौसी)

Spiraea canescens
झिलेटी

Rubus biflorus
Kalo Aniselu
(कालो अइंसेलू)

Plant flowering herbs like these underneath

Cirsium wallichii
Thakal (थकल)

Erysimum hieraciifolium
Titānnō (तितान्नो)

Anisomeles indica
Kale bhido (काले भीडों)

Elsholtzia densa
Kalo Maijeri (कालो माइजेरी)

Cynoglosum zeylanium
Jhalo Kuro (झालो कुर्रो)

Top 10 tips for a healthy hedgerow:

1. Keep the hedge thick and dense
2. Only cut hedges in the winter
3. Don't cut too often or too harshly
4. Encourage native flowering shrubs
5. Encourage flowers and grasses at base of hedge
6. Try and incorporate small trees into the hedge
7. Avoid plants that are toxic to livestock
8. Use plants with thorns that prevent livestock access
9. Choose plants will co-benefits (e.g. Dhatelo)
10. Link your hedge with other hedges and natural habitat to create a joined-up network

Use flowering cover crops

Cover crops protect the soil from erosion, evaporation and nutrient loss whilst simultaneously enriching the soil with nitrogen. They can also have important co-benefits such as providing animal fodder, human food or pollinator forage. Clover (*Trifolium* spp.) is a commonly used cover crop in many parts of the world and serves as a very nutritious cattle forage. It is also rich in nectar, so is a very good pollinator forage plant, especially for honeybees and bumblebees.

See the **Demonstration Farm Manual** for a list of pollinator-friendly plants to use as cover crops.

3. Improving nesting resources

Different pollinators have different life cycles and nesting requirements, so to maximize pollinator abundance and diversity, it is necessary to ensure a large range of different nesting sites are present in the area surrounding the focal crop. For example, honeybees thrive in large cavities such as tree trunks, log hives or other human-made hives; bumblebees normally use cavities in old trees or existing holes in the ground (e.g., mouse holes), solitary bees need bare sloping ground, dead wood or hollow plant stems depending on the species, and many hoverflies require nutrient-rich waters such as those in field ditches. Below are some recommendations to increase the supply of nesting sites for pollinators.

Create a 'Bee Scrape'

Most bee species in Jumla are ground nesting which means they lay eggs and rear their young in narrow tunnels in the ground, often gathering in huge aggregations with hundreds of bees using the same bank. Ground nesting bees, such as mining bees (*Andrena spp.*) are some of the earliest pollinators to emerge in spring, making them vital to the pollination of fruit trees such as apples, peaches and apricots. To promote these bees, you should ensure that there are areas of bare undisturbed soil nearby which the ground nesting bees can use. Bees often prefer sloping banks that face towards the south and therefore get more sun and less rain. You can create areas such as these (known as Bee Scrapes) by scraping the vegetation off a south-facing slope (with a shovel) to create a bare face of soil. An area of 2m x 1m will suffice, but the more the better. Ensure that the area is kept free from any pesticides and disturbance such as walking, ploughing and livestock traffic.

Install bee hotels in crop fields

Bee hotels are simple human-made structures created to provide shelter for insects, in particular bees. They can come in a variety of shapes and sizes depending on the specific purpose or specific insect and can be installed within trees, attached to a wall, or mounted on a post. The simplest designs involve placing a collection of wooden/ straw/ paper /bamboo tubes inside a plastic bottle to provide numerous cavities for solitary bees to nest in. The presence of these structures within apple orchards is known to increase the abundance of a variety of solitary bees, most notably mason bees (*Osmia* spp.), which are some of the most effective pollinators of apple (Gruber *et al.* 2011).

Building a bee hotel

Materials needed:

- Hollow bamboo tubes or rolled-up pieces of paper
- An empty 1 litre plastic bottle
- String
- Sellotape

Construction steps:

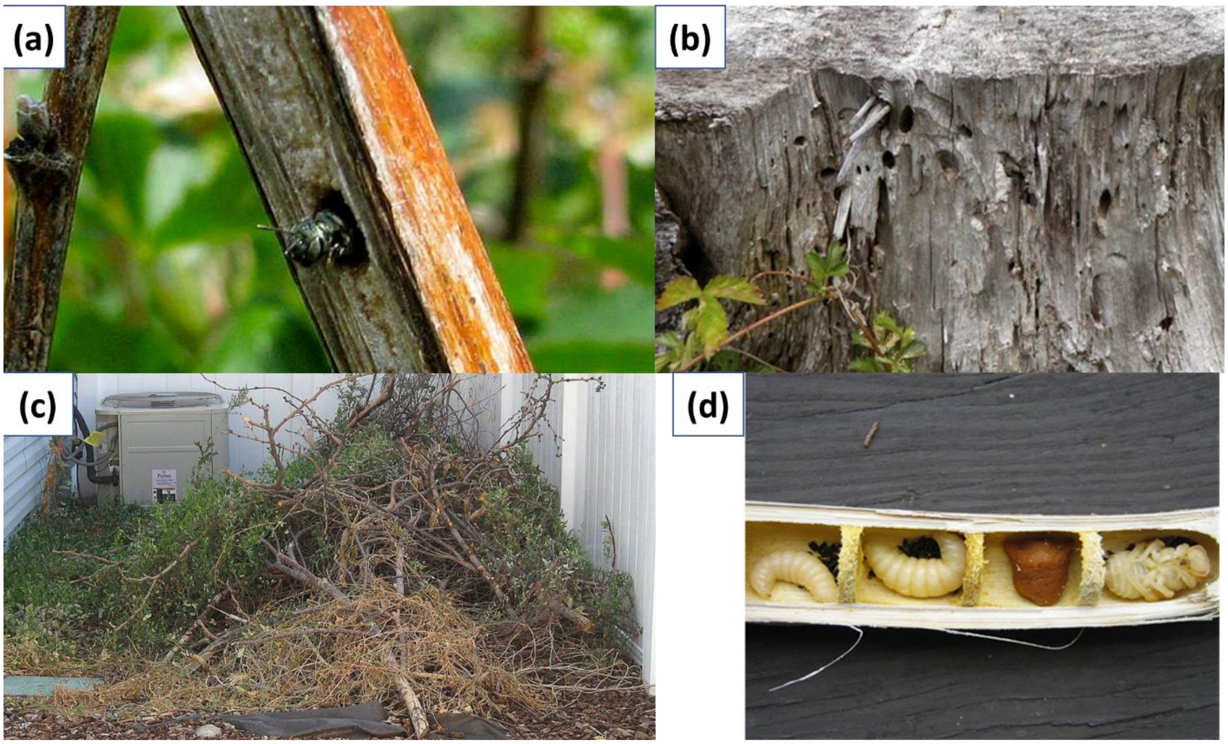
1. Cut top off bottle leaving only the bottom 20cm
2. Roll up paper to create narrow tubes with 3-9 mm diameter holes (see picture above). Try to vary the size of holes so there is a range of options. Alternatively you can use hollow bamboo canes (top right)
3. Cover up one end of the paper or bamboo tubes as bees will only use tubes with closed ends
4. Tie or tape together the whole bundle of tubes with string or Sellotape
5. Insert tubes into the plastic bottle with open ends facing outwards and a 3cm overhang of plastic so tubes are protected from rain
6. Find a spot >1m off the ground and facing southwards (for example on a tree/wall or on top of a post.
7. Fix plastic bottle firmly in place so it doesn't move in wind

Top tips:

- Place chicken wire over entrance of bottle to prevent birds from reaching bees
- Tubes MUST be replaced every 2 years after bees have emerged in the spring – this stops the build-up of disease.
- Ensure bee hotels are NOT exposed to pesticides of any kind

Provide hollow stems and dead wood

Many bees nest inside the hollow stems of plants such as raspberries, grass or bamboo. These can be provided inside a bee hotel, but a simpler way to provide these nesting habitats is grow suitable shrubs inside hedgerows and leave the dead stems over the winter. The Himalayan golden raspberry (Ainselu) *Rubus ellipticus* is a particularly effective shrub for this purpose and should be incorporated into hedgerows. You can also leave small bundles of wheat straw and twigs lying at the edge of fields and large blocks of dead wood such as tree trunks or fallen trees which provide another good nesting habitat. Ensure that these areas are left undisturbed throughout the winter so that bees can nest in peace.



Images of suitable nesting habitat for cavity-nesting solitary bees such as Mason bees. These include a) pithy hollow stems such as raspberries, b) dead wood, c) piles of dead branches. Panel d shows the stages of solitary bee development inside a hollow stem. More information from Xerces.com

Leave areas of stagnant water

Hoverflies (Syrphids) are very important pollinators (particularly for apples) and have a very different lifecycle to bees. Many species (including the drone flies - *Eristalis*) lay their eggs in water and the young larvae (like small worms) develop inside the water before emerging as flying adults later on. Small pools of nutrient rich water with lots of rotting vegetation are perfect for drone flies, so it is helpful to maintain these areas near your crop fields. It is a good idea to dig a small shallow pond on the farm or fill an old bucket or pot with water and put some leaves in it to create a body of nutrient-rich stagnant water (See images below). This is the perfect home for drone fly larvae. Be very careful that this doesn't create a hazard for small children though – either use a small vessel like a bucket, or cover the pond with a metal grid so children cannot fall in.

Image of drone fly (Eristalis) larvae (left) which develop into effective pollinators as adults and suitable habitat for developing hoverflies (right) – a bucket with water and rotting leaves.

Provide good-quality hives for honeybees

Placing a honeybee hive near your crop is the simplest and fastest way to increase pollination services. However, beehives vary greatly in quality and it is important that the hive you use is suitable for the honeybee species and the conditions. A hive must provide bees with a clean and safe living environment which minimises exposure to intense heat, cold and rain; it must protect colonies against predators such as pine martins and minimise the spread of disease. Beehives must also be well-maintained following good hygiene practices (see next section).

4. Protection from disease and chemicals

Managed honeybees and wild pollinators are highly susceptible to disease and chemical pesticides, so carefully managing these two factors is essential for maintaining healthy pollinator communities. This section outlines some specific recommendations for reducing disease rates amongst honeybees and generic advice for maintaining the health of wild pollinators.

Maintain good hygiene practices in honeybee hives

Once a honeybee colony is infected with a disease, it can easily spread to other nearby hives if good management practices are not followed. Firstly, the infected hive should be moved away from the vicinity of non-infected hives to reduce the chances of disease spread. Any equipment such as frames, knives etc. used in hives (even non-infected hives) should be thoroughly cleaned and sterilized using boiling water or soda crystals (1kg of washing soda to 5 litres of water) before being used on another colony. If a colony dies out from disease, the hive should either be burned or thoroughly cleaned using soda crystals and water and a scraper to remove all remaining honeycomb, wax and propolis. Infected hives and hive material should NEVER be left lying in the open as bees from other colonies may steal the infected material and take it to their own colony.

Boost the strength of the infected colony

If a colony starts to suffer from disease, it is sometimes possible to strengthen it enough to overcome the disease. This can be done by supplementing the colony with sugar water to increase its energy or introducing fresh brood (eggs, larvae or pupae) from a healthy uninfected colony. Re-queening the colony can also help. However, no materials or brood from an infected colony should EVER be moved to another colony.

Use larger cleaner hives

When only a few individuals in a honeybee colony are infected, the colony will isolate these individuals and prevent them from coming into contact with healthy brood and spreading disease. However, when hives are very small and cramped with no space for separate brood chambers, disease spreads amongst a colony much more quickly.

Reduce stress from other factors

Pollinators (both wild and managed) are most susceptible to disease when they are also stressed by other factors such as lack of food, heat, cold, or exposure to pesticides. Providing an abundant and diverse supply of flowers in the vicinity of the nest has been shown to reduce rates of disease because better nourished bees have stronger immune systems and are therefore more able to resist disease. Likewise, providing bees with suitable nesting sites which protect them from extremes of temperature and natural predators will also help to reduce disease rates.

Carefully manage pesticide use

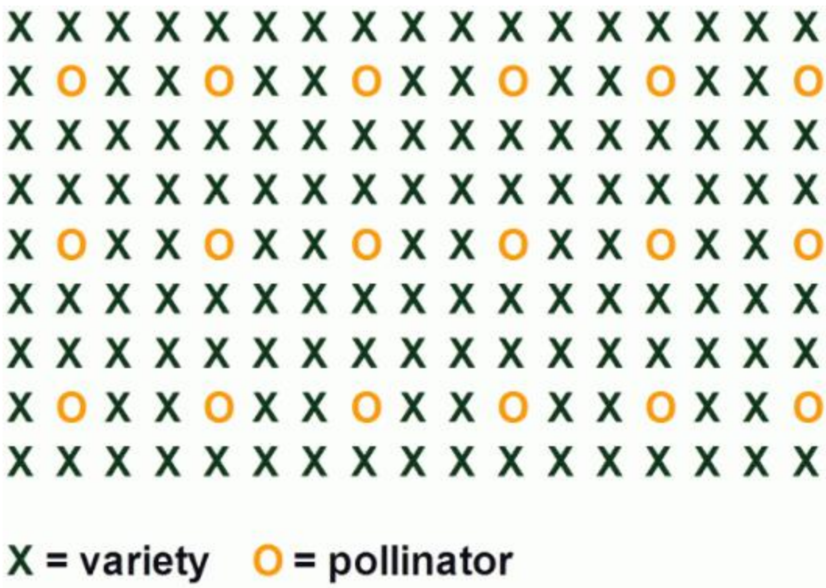
Pesticides are designed to kill insects so are often very harmful to wild and managed pollinators. This can also be true for organic/botanical pesticides, though they are generally far less harmful. Minimising chemical pesticide use is an obvious way to support pollinators, but the timing of application can also be important. Pesticides (including organic pesticides) should NEVER be sprayed during, or immediately before the time of crop flowering as this is when pollinator numbers are at their highest. Instead, if completely necessary, pesticides should be applied AFTER crop flowering when pollinators have moved elsewhere.

5. Apple pollination management

All of the above procedures are relevant for enhancing the pollination of any pollinator-dependent crop including apple, however, there are a few additional pollination management guidelines which are specific to apple. These are outlined below.

Ensure close proximity to an appropriate polliniser

All apple cultivars require cross-pollination with an appropriate pollinizer to ensure commercial quality fruit yields. Many agricultural insurance companies in Karnali Province even insist that farmers incorporate these trees into their orchards. Red delicious – the variety grown throughout most of Jumla and Mugu – is particularly reliant upon an appropriate pollinizer which MUST flower at the same time as Red Delicious and have compatible pollen. The most effective pollinizer for Red Delicious is Golden Delicious. Golden Delicious trees should be planted very close to crop trees (around 5-20 metres) and should be placed regularly throughout the orchard – at least one pollinizer for every 10 crop trees (see image below). To further improve pollination services, pollinizer branches can be grafted on to each crop tree so that the distance is minimised. Alternatively, pollinizer branches can be cut just prior to flowering (whilst still in bud) and placed in water and hung in the crop tree canopy so that they flower within the branches of the crop tree (see image below).



Example of an effective planting scheme to maximize proximity to pollinizer

Pollinizer branches cut and hung in a plastic water bottle in each apple tree during flowering to maximise proximity to compatible pollen.

Introduce honeybee hives

Although healthy and abundant wild pollinator communities can be sufficient to achieve high quality pollination of apples, the short flowering time of apples means it is a risk to rely on wild pollination services alone, especially if the weather is poor during flowering. Introducing honeybee hives is a highly effective way of improving apple pollination, especially when combined with other management practices to increase habitat quality and wild pollinator abundance. One healthy hive for every 5 Ropanis (0.25 ha) of apple is the recommended stocking density and hives should be placed in a slightly elevated position, not directly on the ground, and where there is ample sunlight. The entrance should be shielded from direct wind and be clear of blockage or obstruction such as branches or tree trunks. The entrance should face into the centre of the orchard as bees are most likely to forage directly in front of the hive.

Minimise other flowers during apple flowering

Although a diversity of flowers is important for pollinators, it is better not to have too many flowers in close proximity to apples during the short period of apple flowering. These non-apple flowers may attract the pollinators away from apple flowers, so it is very important NOT to plant other crops which flower at the SAME TIME as apple. Try to arrange your planting scheme so that crops flower before and after apple, but not at the same time. Wild flowering plants are not a problem as they provide important nutrition to pollinators and will be very important to pollinators before and after flowering.

Questions to facilitate understanding

1. What are the three main things we can do to support pollinators on farmland?
2. What is a hedgerow and why is it good for pollinators?
3. List five wild plants that are particularly good for pollinators
4. What actions can we take to protect pollinators from disease and pesticides?
5. What will you change about your farm to make it better for pollinators?

Topic 8: Integrated Pest & Pollinator Management (IPPM)

- What defines a pest
- Learn how to manage pests in a way that doesn't harm pollinators
- Understand the role of pests in the agroecosystem
- Understand the principles of Integrated Pest Management (IPM)

Learning goal

To understand what pests are and how they can be controlled without harming pollinators and other important components of the agroecosystem.

Key goals:

- Explain what defines a pest
- Classify the different types of pest
- Learn what makes a pest problematic and how to identify this point
- Learn how pests and pollinators can be managed through IPPM

Duration

One hour of formal presentation about Integrated Pest Management principles. Two hours of field visit to identify and categorise pests. 1 hour discussion session in classroom to develop a pest management plan for the farm.

Materials required:

Cards, Pictures of common pests, paper to write pest management plan, wall chart.

<u>Procedure:</u>

1) Formal presentation to explain the definitions and categories of pests and the principles of Integrated Pest Management (IPM).

2) Visit to the field to observe different types of pests, categorise them and discuss the point at which they would become a problem to farmers

3) Return to classroom and conduct group exercise to devise an Integrated Pest Management plan.

- Participants are divided into small groups and given a set of blank cards and a marker pen
- Each group should discuss all of the pests that they commonly encounter on their farms and then write each pest on a separate card.
- Ask the participants to divide the cards up into piles based upon the type of pest that they are (weed, pathogen, herbivore)
- Now they should arrange the cards in order of least to most serious and see if they agree upon which pests are the worst.
- For each pest, they should discuss the following things:
    - <u>Action threshold</u> – at what point would they consider this pest to be a problem?

    - Monitoring – how often would you need to check your crops for this pest and what signs would you look for?
    - Prevention – what actions would they take to prevent this pest from establishing?
    - Control – if this pest became a problem, what actions would you take to get rid of it?
- One the group has agreed upon these four things, someone should turn over the card for that pest and write their answer on the back.
- Now the discussion should open up to the whole group and they should see whether they agree upon the management plan. The facilitator should listen carefully and write down the consensus from the group on a separate piece of paper. This will become the adopted Integrated Pest Management plan for the group.

Learning materials:

1. What are pests?

An agricultural pest is any plant, animal, microorganism or pathogen which is unwanted and causes harm to crops or livestock. It is important to realize though that some things we think of as pests actually have unexpected beneficial effects, so it is important to understand more about them and how they fit into the agroecosystem. Each pest has natural enemies, including predators, parasites and pathogens that keep its numbers in balance. If the pest is a weed, it will have herbivores that reduce its growth, whereas a leaf eating insect, for instance, will have a range of predators and parasites attacking it. The presence of natural enemies ensures that pests rarely destroy the entire crop that serves as their food source. To maintain their life cycles, natural enemies must have some food source. This means that we have to accept the existence of at least a small number of pests in agricultural fields, otherwise natural enemies, especially those that eat only one type of food, cannot survive. If they starve, their disappearance will lead to an explosion in pest numbers.

In determining whether an insect or other animal eating plant parts is a pest there are many factors to consider. These include:

- How many pest individuals appear relative to the numbers of their natural enemies?
- At what stage of crop development they damage the plant, and to what extent the plant can overcome the damage?
- What part of the plant they attack relative to the economic value of that part
- How they may be controlled, how difficult this is and what it costs relative to the loss they are likely to cause?
- Natural enemies are most functional agents they manage the pest population naturally.

The three main types of pest are outlined below:

1. Weeds

Weeds are unwanted plants that may compete with crop plants. We usually think that they have no beneficial effects when they grow on cultivated land; however weeds are not always harmful. Weeds can be divided into three categories: grasses, sedges and broad-leaved plants.

Weeds can cause losses when:

- They compete with the vegetable crop for nutrients, light, water and growing space.
- Their removal is costly.
- They provide a refuge for insect pests allowing their survival during periods when there is no crop growing in the field.

Weeds may be beneficial when:

- They provide a source of green manure that supplies nutrients and organic matter improving the soil structure, when applied as fertilizer.
- They form a covering layer over the soil (mulch). Mulches protect the soil from the light that causes the loss of water and organic matter.
- They provide a source of food for pollinators and act as a refuge for natural enemies.
- They can be harvested to feed livestock.

2. Herbivores

Herbivory is the act of eating plants and may occur above or below ground. Herbivores may eat any part of the plant above the soil including leaves, stems, flowers, fruit and any part of the plant below the soil including roots and tubers.

The herbivores that are most damaging to farmers are generally invertebrates like snails, slugs, mites, millipedes, worms and species of insects. Insect herbivores are the most numerous and varied - it has been estimated that approximately half of all living insects are herbivores. Some large insect groups are almost exclusively herbivores, including moths and butterflies, weevils, leaf beetles, gall wasps, leaf-mining flies and plant bugs.

Herbivores can cause considerable damage to crops, but there are also a number of important benefits they provide, for example:

- *Increasing nutrient uptake and production by plants.* Low level herbivory may remove aging roots and leaves, initiating new growth of young roots and shoots, which are more effective at nutrient absorption and production.
- *Increasing the quality of leaf litter and soil.* Many herbivores favour young foliage, which has a higher nutrient content than old leaves. Herbivores therefore, return high concentrations of nutrient to the soil as faeces. This results in leaf litter with a higher nutrient value.

- *Control of weed populations.* As well as eating crops, herbivores also eat weeds and therefore reduce the level of competition between crops and weeds. Various insect herbivores are often used as a form of biological control for specific weeds.
- *Provide valuable forage for crop pollinators.* Many weeds have abundant nectar and pollen rich flowers which provide a source of food for insect pollinators, especialyl when crops are not flowering.
- *Maintain natural enemy populations.* To maintain their life cycles, natural enemies of herbivores (for example, parasitoid wasps, ladybirds, hoverflies and birds) must have some food source. This means that we have to accept the existence of at least a small number of herbivores on our farm, otherwise natural enemies, especially those that eat only one type of food, cannot survive. If they starve, their disappearance will lead to an explosion in herbivore numbers which would be far more destructive.

3. Pathogens/ Diseases

Diseases of plants, like those of humans and animals, may be caused by various organisms including:

- Nematodes - these are tiny worms that live in the soil and in root tissues. Some species are visible to the human eye with the aid of a magnifying glass, but most can only be seen with a microscope. Their presence is suspected from the symptoms they Cause. They cause blister-like swellings or cracks on the edible roots, gall-like swellings on the fibrous roots, and large portions of the root system may die. Nematode egg masses survive in the soil and rotting plant material may harbor the juvenile stages. They can be transported by irrigation water and disseminated through infested planting material.
- Fungi – these usually cause affected plant parts to rot. Other symptoms include the appearance of spots, powdery areas, or masses of filaments. Powdery growths are composed of fungal spores that can spread to other plants. Fungal spores are like the seeds of green plants-when we observe them, we can be sure that the development of the fungus within the plant has already occurred. Common vegetable diseases caused by fungi include root rots and black rots.
- Bacteria - these are smaller than nematodes and fungi. They are not visible except under a microscope. Bacteria can cause the formation of wound-like lesions, rotting, and plant death.
- Viruses – are much smaller than any other creature and can only live and multiply inside their hosts (or victims). Once a virus enters a cell in the body of its host, it will take over the management of the cell and force it to produce more viruses identical to itself. These viruses can then infect more cells. Viruses can attack both animals and plants, but specific types of viruses mostly have specific targets. Each virus causes a specific disease. The symptoms of virus attack on plants include dwarfing, leaf curling, and the appearance of purple pigment, yellowish spots, yellow veins or mosaic patterns. Heavily virus-infected plants can be detected by their stunted growth and/or yellow leaves of irregular shape. Many viruses are transmitted by aphids or other sucking insects and only a few insects can infect an entire field with virus.

2. Managing pests

Farmers and a range of other stakeholders consistently list pest and disease outbreaks as the most important issue in their farming. Thus, for pollinator-friendly farming to be successful, it is essential to provide farmers with products, technologies and management practices that allow them to control pests and diseases without having to resort to agrochemicals which disrupt the agroecosystem and harm insect pollinators. These solutions need to be affordable and readily available to farmers and should not burden them with large amounts of additional labour. Integrated Pest Management (IPM) is an approach to pest control that reduces reliance on agrochemicals by utilising natural ecological process. It has four important components:

1) Setting thresholds of acceptable pest levels
2) Monitoring and identification of pests
3) Prevention of pest outbreaks
4) Control of pest outbreaks.

These four components are outlined in detail below along with some practical guidelines for each one.

1) Setting thresholds

Before taking any pest control action, IPM first sets an action threshold – this is the point at which pest populations or environmental conditions indicate that pest control action must be taken. For example, sighting a few aphids on a tree does not necessarily mean that pest control is needed, but at some point, those aphids might start to pose a genuine risk to the farmer's yields. This 'action threshold' - where the pests are deemed to be an economic problem - is the point at which further action will be taken.

2) Monitoring and identification

Not all insects, weeds, and other living organisms require control. Many organisms are totally harmless, and some are even beneficial (e.g., pollinators or pest predators). Farmers must therefore be able to identify the animals, plants or diseases that actually pose a serious risk to their agriculture. Once they have identified these pests and decided upon an action threshold for each one, they will know what to look out for and can monitor pest levels regularly to see when they are becoming a problem. Only when the action threshold is reached do farmers need to take action and manage the pest. This process avoids excess labour as well as the unnecessary or inappropriate use of pesticides or other pest control measures.

3) Prevention

As a first line of pest control, IPM programs work to manage the farmland to prevent pests from becoming a threat. In an agricultural crop, this may mean using cultural methods, such as rotating between different crops, selecting pest-resistant varieties, and planting pest-free rootstock. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment. Prevention of pest outbreaks can also be achieved by managing the surrounding environment appropriately. For example, a healthy diverse environment with lots of surrounding native habitat (e.g., forests, grassland and hedgerows), will support abundant populations of natural pest enemies which are highly effective at keeping pest levels low.

Prevention options:

1. Maintain areas of natural habitat. Ideally these would be relatively large patches of native habitat such as forest, grassland or shrubland, but even small patches of bushes and trees, or a patch of weeds at the edge of a field can support populations of natural pest predator such as wasps, ladybirds, hoverflies, insect-feeding birds or carabid beetles. To be most beneficial, these areas should not be sprayed, cut, burnt, ploughed or excessively grazed. These areas will also serve the dual benefit of promoting pollinating pollination services.
2. Promote the use of hedgerows. As well as being beneficial for pollinators and soil stabilization, hedgerows are excellent homes for natural pest enemies. Hedgerows should be planted along the edge of each field on the demonstration farms (See Figure for guidelines on planting hedgerows).
3. Rotate crops regularly. If the same crops are grown repeatedly in the same areas, populations of pests and disease will slowly build up in the soil and become a problem. Instead, you should rotate crops regularly on the demonstration farms to prevent the build-up of specific pests and enrich the soil. Rather than just rotating the species of crop you are growing, try to rotate between entirely different crop groups so that the soil experiences a full range of different plants. Here are some examples of different crop groups that you can rotate between: a) ***Cereals*** e.g., wheat, maize, barley etc.; b) ***Root vegetables***: e.g. carrots, beetroot.; c) ***Legumes***: e.g. peas, beans; d) ***Brassicas and salads***: e.g. cauliflower, cabbage, mustard, spinach, lettuce; e) *Onion family*: e.g. onions, garlic, leeks, shallot; f) ***Potato family***: e.g. potato, tomato, eggplant, capsicum; g) ***Cucurbits***: e.g. courgette, cucumber, pumpkin, squash.
4. Intercropping – planting multiple crops together in close proximity can reduce pest outbreaks by confusing insects and reducing their ability to specialise on one crop. Some crops or plants will also attract natural pest predators whilst others (such as marigold, chili, tobacco etc) will repel pests. Many of the same plants used as botanical pesticides (Figure 7l) can also be intercropped as live plants to repel pests – try this on the demonstration farms.
5. Remove fallen leaves and dead crop material. Pathogens causing diseases do not appear spontaneously; they always come from other diseased plants or their remains, even though these may be distant and the disease organisms may have been carried long distances, for example, by wind, insects or some other means or from a previous cropping cycle in the same field. Many fungal and bacterial diseases can survive on plant debris or in the soil for long periods of time until new host plants become available. Disease pathogens often survive between cropping seasons in soil, especially in crop debris, so it is important to remove and burn any fallen plant material from your fields before planting new crops and to clean agricultural equipment before moving it between fields.
6. Create physical obstacles. Many pests reach plants by crawling over the soil (e.g., caterpillars) or walking into the field (e.g., deer). Introducing structures that make it more difficult to access the crop can be very useful, for example a fence or hedge to keep out large herbivores, and small stones or eggshells sprinkled on the ground to stop insects crawling over it. Herbivores also often target the

softest and most tender parts of the plant – e.g., the stem of a young seedling, so it may be useful to put a small barrier like a plastic bottle around the stem to prevent herbivores accessing it.

4) Control

Once monitoring, identification, and action thresholds indicate that pest control is required, and preventive methods are no longer effective or available, IPM programs then evaluate the proper control method both for effectiveness and risk. Effective, less risky pest controls are chosen first, including highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less risky controls are not working, then additional pest control methods might be employed, such as targeted spraying of organic pesticides.

Control options:

1. <u>Bordeaux mixture</u>. This is a combination of copper sulfate, lime, and water and is an effective fungicide and bactericide that has been used for decades to control diseases of fruit and nut trees, vine fruits, and ornamental plants. When mixed in the correct order, these minerals provide long-lasting protection to plants against diseases. Some examples of its use are in the treatment of fire blight, apple scab and papery bark fungus on pears and apples; leaf curl and shot hole on peaches and nectarines and walnut blight on walnut. Spraying or painting is best done in the autumn after leaves fall and in the early spring before leaves emerge. Bordeaux works far more effectively as a preventative than a treatment method so don't wait for a disease to appear because that may be too late.
2. <u>Pheromone trap</u>. This is a type of insect trap that uses pheromones (sex hormones) to lure insects away from crops and into the trap. It is particularly effective for insect pests such as moths (e.g., the codling moth - *Cydia pomonella* – on apple), beetles such as stem borers, and leaf miners. They can often be purchased in local markets or the AgriVet store and can be hung in apple orchards or placed next to crop fields.
3. <u>Organic pesticides.</u> There are now a number of commercially-available organic pesticides which are produced from natural materials and often have lower toxicity to many organisms. Some examples are ***Neem-based pesticides*** (acts as a fungicide and hormone disrupter of insects), ***mineral oil formulations*** (which suffocate insects by creating smothering them), ***liquid soap mixtures*** (2 tablespoons liquid soap to 1 litre water) which dissolve oils on insect bodies and ***diatomaceous earth*** (calcium dust) which dries out insects bodies by absorbing their water. Many of these products are highly effective but they may often be unavailable or unaffordable in poor remote regions such as Jumla. It is also worth noting that although these products are less toxic than most chemical pesticides, they still function by killing insects and other pests and can still be toxic to humans, so should always be used with care and not applied at times of flowering when they may poison pollinators.
4. <u>Botanical pesticides.</u> A more affordable and locally accessible alternative to commercial organic pesticides are home-made botanical pesticides. These can be made by crushing up a variety of

locally-occurring plant species with pesticidal properties and mixing them in a drum of cattle urine. The mixture is then left to mature for 3-4 weeks before spraying directly onto crops. These mixtures have the advantage of fertilizing the plant at the same time as controlling pests and cost very little to produce. The only equipment required is a simple plastic drum and spray device. See **Figure 5a** for examples of appropriate local plants to use as botanical pesticides. It would be highly beneficial to trial a variety of these pesticidal plants with farmers on the demonstration farms and identify the most effective and most easily propagated plants so that production can be scaled-up and promoted more widely. See here for evidence of effective use in Nepal and instructions for preparation. Extreme caution must be taken with any of these plants and mixtures as they are likely to be partially toxic to both humans and animals.

5. Biological control agents. Biological control (biocontrol) uses one living organism to control another. It is a way to control weeds and pests by introducing a natural enemy or predator into the environment. Common examples include ladybirds which eat aphids, and parasitic wasps which lay their eggs in many different species of insect pests such as caterpillars, aphids and flies, eventually killing them. Maintaining a diverse and healthy ecosystem around the farm will increase populations of natural pest predators, but it is also possible to purposely rear and introduce specific biocontrol agents. Around the world there are a number of commercially available biocontrol agents such as ladybirds, mites, wasps, nematode worms and bacteria which can be purchased in packets and introduced into cropland. For example, the wasp *Aphelinus mali* is widely used to control the woolly apple aphid which is a major problem in Jumla. I am not aware of any existing biocontrol initiatives in Jumla but it would be worth investigating whether they exist.
6. Hand-picking pests. For some larger insect pests like caterpillars, slugs and snails, hand-picking them off your plants and feeding them to livestock like chickens can be a very effective strategy. This works particularly well when pests are at low numbers so it is feasible to find and remove most of them.

Questions to facilitate understanding

1. What makes something an agricultural pest?
2. What are the three main types of agricultural pest?
3. Why can pests sometimes be beneficial for agriculture?
4. What are the four components of Integrated Pest Management?
5. Give three examples of pest prevention methods and three examples of pest control methods.

Topic 9: The concept of an agroecosystem

- Understand what an ecosystem and an agro-ecosystem are
- Understand the meaning of ecological interactions
- Understand the different trophic levels
- Understand the food web

Learning goal

To understand what an ecosystem is and how pollinators fit into this ecosystem. To understand the interactions of different species in an ecosystem and how this makes the ecosystem healthy. To understand the farm as an ecosystem and think about the different animals and plants on a farm that promote its functioning.

Key goals:

- Explain the concept of an ecosystem
- Understand the tropic levels in an ecosystem.
- Build awareness of the relationships that exist between so many of the living and non-living things that are found in our environment.
- Appreciate that if one thing in this network of interaction is changed, it can influence all of the components of the ecosystem.
- Become more aware of the things and interactions that make up the ecosystem of our farms-the " Agro-Ecosystem"
- Become aware of the interactions that encourage pollinators to persist in the Agroecosystem.
- Start to use our understanding and observations of the Agroecosystem as a basis for decision making about crop management.

Learning concept

- The participants will learn about the ecosystem on their farm and the different roles of the all the plants, insects and microorganisms.
- The participants will learn about how pollinators fit into the ecosystem

Duration

Two hour of formal presentation about the ecosystem/agroecosystem and the different trophic levels. Then the participants will visit the field for 2 hours to understand the various components of the ecosystem and draw a sketch of an ecosystem and food web.

Materials required:

A ball of wool or string (cut into lots of lengths of 3 metres long), cards, masking tape, marker pens, drawings of specific pollinators, chart to draw an agroecosystem

<u>Procedure:</u>

1. Theory session

The facilitator familiarizes the class about the concept of an ecosystem and the explains how all living things are somehow connected based on their interactions with each other. They also explain the different categorizations of life, like producers, consumers, predators etc.

2. Classroom exercise

- The facilitator should prepare the exercise by taking the same number of cards as there are participants and writing the name of a component of the ecosystem on each card (e.g., Crop, bee, hoverfly, butterfly, wild flowering plants, water, pesticides, pests, natural enemies, soil, etc.).
- The participants form a circle and pick one card each. Each participant fixes the card on his/her body so all can see it.
- The participant who picked the card showing 'crop' stands in the middle of the circle holding their piece of wool or string.
- The participant who represents to crop says "I am the crop and I need the bee to visit me to be fertilized and produce fruit". They hold one end of the string and pass the other end to the person who represents the bee to show this connection.
- Now the bee says "I am the bee and I need to visit other wild flowers to get enough food to survive". They then hold a new piece of string and pass the other end on to the wild flowers. The bee can also hold another piece of string and pass this on to the person representing the tree which the bee needs for nesting.
- Repeat this process and encourage participants to think about all of the different components of the ecosystem they are connected to. For example, the hoverfly will be connected to the crop and wild flowers, but also to the crop pests (like aphids) because they eat these. Each card or person can be visited more than once.
- The participants are asked why they are connected, what they can learn from the exercise and if they can group together the cards/components in the ecosystem (e.g., living and non-living, producers and consumers, etc.).
- The facilitator then introduces the concept of tropic levels within the ecosystem.

3. Field observation

- Divide participants into small groups
- Each group will go to the field and do the following
- Look around as far as the eye can see, and as close as the eye can see
- List all the living and non-living things they can see
- Discuss how they are connected or how they affect each other.
- Spend some time looking at what is visiting crop flowers.
- After 20 minutes of observation, discussion and note-taking return to the meeting place
- Each group to make a picture showing all the things that they observed and draw lines to show which things are connected or affect each other.
- Each group gives a presentation in which they explain what they have drawn to the big group.

4. What is this? What is that? Learning concept on AESA

- Let participants walk into a field as a group.

- In this group, take turns in the following roles:

a. The 'farmer' should take anything in the crop ecosystem (pollinator, pests, natural enemies, weeds, others) and ask, "What is this?" The other members will act as "recorders" and must write down questions and responses. The "facilitator" should respond with one of the following type of responses: 'That is a good question'. "Where did you find it?" 'What was it doing' 'Did you ever see it before'? 'What do you think it is'? (Keep asking questions). Use this especially when you know what the specimen is. Try not to give the answer!

b. If the question is to be answered, the "facilitator" should avoid the answers, which give more emphasis to identification. Rather, the function of the organism should be emphasized. 'This is an insect that feeds on the plant'. 'It is not actually a problem insect until there are very many'. 'There are many organisms which eat this insect, including spiders and parasites' OR, 'this is a spider that eats insects and is a friend'. 'It happens to be called a hunter because it moves around the field searching for insects' OR, some other responses that only give biology/ecological information.

c. Never give the answer with a name. That only kills the question. The question is a chance to learn.

- After the members had taken their turns, return to meeting place/shade and discuss the experiences.

Learning materials:

1. Ecosystem and Agro-ecosystem

Ecosystem:

An ecosystem is an area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life. An ecosystem is formed by the interactions between all of these living (biotic) and non-living (abiotic) components.

Living elements include plants, insects (pests, pollinators, natural enemies, and decomposers), microbes and other living creatures, whereas non-living elements are physical factors such as temperature, water, wind, sunshine, rain and soil.

Each element has its own special features and role in the system that in turn influences all of the other parts of the system.

When different parts of the system interact, (e.g., one animal eats another, or a plant grows in soil), energy and nutrients are transferred between the different parts of the system.

Some interactions result in benefits, such as increased productivity, while others lead to losses. There is a need to maximise the positive results and to minimise the negative ones through better management. Hence, farmers should understand the functions and interactions of various components.

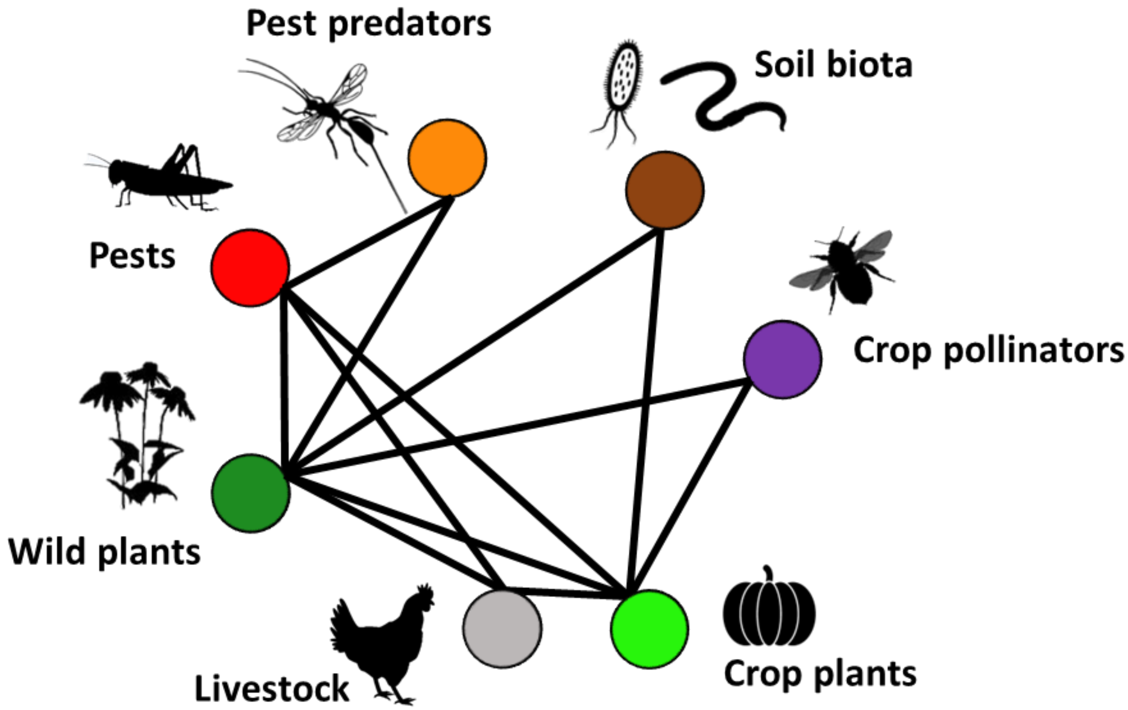
Agro-ecosystem

An agroecosystem is the community of plants, animals, crops, livestock and microorganisms that interact to make up a farm. It includes the crops that you grow, the insects that eat or pollinate them, the livestock, the pests, the microorganisms in the soil etc. It also includes the surrounding habitats such as grasslands, hedgerows and forests which influence the farm.

All of these different components of the agroecosystem are connected to each other in some way. For example, the health of crops is influenced by the health of the soil, the weather, the nutrients, the herbivores that eat them, the insect pollinators, the microorganisms etc. Other species will in turn influence these ones – for example wild plants will support pollinators, natural pest predators like wasps, hoverflies and bird will reduce herbivore numbers, surrounding forests will control water availability etc.

In a well-functioning agroecosystem, all of these different things are balanced – the pollinators are abundant and healthy, the soil is nutritious and holds lots of water, the herbivore populations are kept low by the natural enemies, the surrounding habitats are healthy and diverse etc. When this is the case, crops and livestock will flourish.

However, an agroecosystem can very easily become unbalanced. If too much natural habitat is cleared, too many wild plants are removed, too much pesticide is sprayed, or too much fertilizer is applied to the soil, the wild plants, animals and insects will suffer and this balance will be disrupted. Pests may become very abundant without any natural predators to control them, pollinators may die out, the fertility and water retention of the soil will reduce and crop and livestock health will suffer. Understanding your agroecosystem and all of its connections is very important for keeping it in balance.



2. Ecological relationships

Within an ecosystem, each species has its own role and contributes to the balance within the ecosystem (or farm). It is useful to understand the different roles that are found within an ecosystem so that we know what each species is doing and how management actions might affect them. Species can be divided up into different levels based upon their feeding (trophic) relationships:

1st level organisms (producers)

1st level organisms are primary producers which transform sunlight into energy. Plants are the most important producers – they absorb water and nutrients from the soil and obtain energy from the sun, and transform these into leaves, stems, roots, flowers, and fruits. In a farm, the primary producers are the crops, along with any associated trees, hedges, cover crops and weeds. On farms, some primary producers like weeds may be competitors of water, light, nutrients, and space. A weed is therefore defined as a producer that is not wanted by mankind at that time and place. But even some weeds can provide benefits to farmers, if for example they are gathered for medicinal purposes, or provide food for pollinators or natural enemies that then visit the crops.

2nd level organisms

These are animals that feed on plants. They include grazing animals, like cows, goats, antelope or herbivorous insects like caterpillars, beetles and aphids, and also very small consumers like viruses, and fungi. In a natural ecosystem these consumers are an important part of the cycle.

On farms, these consumers are usually referred to as pests because they eat crops. But pests are defined by their populations and not by their functions. When an organism reaches a high level of damage on the plants then they are pests. If the population is low then they are not pests. But if there are no pests at all there will be no predators, parasites, or natural enemies.

Pollinators also feed on plants: the pollen and nectar of plants. They are therefore 2nd level organisms.

3rd level organisms

These feed on the 2nd level organisms and include creatures like parasites and predators. In a forest these might be foxes or big predatory cats like leopards. In a farm, 3rd level organisms are:

- Predators e.g., spiders, wasps, ladybird beetles, hoverflies, owls, cats etc.
- Parasites e.g., virus that attack plant fungi and bacteria.

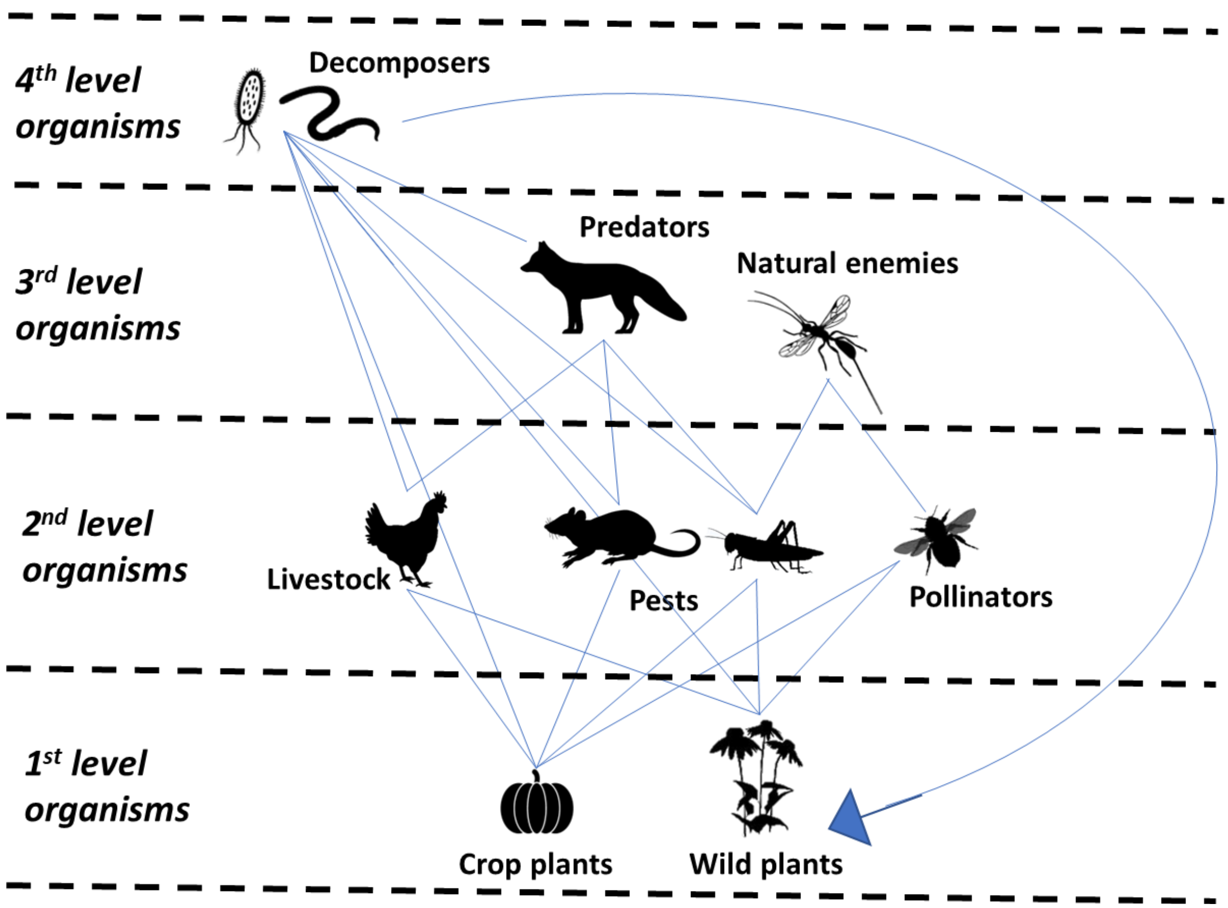
These organisms are usually called "natural enemies or friends of the farmers", because they attack things that could become pests. Preserving these organisms is important to keep the 2nd level organisms from becoming pests.

4th level organisms

These are decomposers. They include bacterial, fungi, and insects that feed on dead plants. The organisms cycle the nutrients in the system back in the soil. They are very important on farms for keeping the soil fertile and healthy and preventing the build-up of dead animals and plants which could cause disease and attract pests.

Organisms within each of level interact with organisms in other levels by eating them or being eaten by them. It is these interactions that keep an ecosystem balanced and healthy. The same is true on a farm.

A simple farmland agro-ecosystem



Questions to facilitate understanding

1. Describe all the different types of creatures that make up the agroecosystem on your farm – how are they connected?
2. For each of the 4 trophic (feeding) levels, give three examples of organisms found on your farm
3. Explain why the wild plants and weeds on your farm might actually benefit your crops
4. How might pesticide application change the balance of your farmland agroecosystem?
5. What does a healthy agroecosystem look like?