Report of Techical Support on:

STRENGTHENING AGRO-ECOSYSTEMS RESILIENCE FOR CLIMATE CHANGE ADAPTATION TO IMPROVE FOOD AND NUTRITION SECURITY (TCP/NEP/3701)

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Thank you all.

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LIST OF ACRONYMS

FAO	Food and Agriculture Orgnisation of the United Nations
FGD	Focus Group Discussion
KII	Key Informant Interview
TCP	Technical Cooperation Project
FFS	Farmers Field School
IPM	Integrated Pest Management
IPPM	Integrated Pest and Pollination Management
MASL	Mean Above Sea Level

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EXECUTIVE SUMMARY

Agroecosystem is the basis of humankind's existence and the foundation of human civilization, in which all biotic agents - crop pollinators, predators, parasites, pathogens, earthworms, scavengers and detrivors and abiotic factoes interact. There seems complex web of threats: exposure to pesticide, loss of foraging habitats, and changes in landscapes and resulting pressure on beneficial organisms in context to climate change and much more complexities remain to be understood for their conservation and managemnt. It is difficult for farmers to identify the key drivers and barriers (climate related and human interventions coupled by use of improper agricultural practices, such as imprudent use of agro-chemicals, mono-cropping, flooding irrigation, etc.) that are contributing to the deterioration of essential elements of agro-ecosystem services. The technical support through the project to the Government of Nepal focuses addressing present challenges offering diversification in agricultural activities and integrating different agro-ecosystem services through conservation of natural enemies, pollinators and other beneficial organisms for food security, i.e. i) conserving biodiversity and population of natural enemies, pollinators, and decomposers; ii) attaining sustainable agriculture and increasing crop yield and farm income through restoration of agro-ecosystem services; and iii) enhancing food security and livelihood of smallholders farmers. The project objectives, specific activities and achievements of the poject are as follows.

General Objective: The general objective of the study is the strengthening of agro-ecosystems resilience for climate change adaptation and improving ecosystem services for sustainable crop production to ensure food and nutrition security.

Specific Objectives: The specific objectives of the proposed study are as follows. Carry out baseline survey (farmers perception survey) and prepare base line data on agro-ecosystem services in the selected agro-ecosystems,

- Desk reviews to prepare bibliographic databases and recommend the good conservation, and management package of practices for agro-ecosystem services on Apple, Mustard, Buckwheat, Citrus for the selected agro-ecosystem,
- Crop field survey and sampling (sampling, collection and preservation of the samples of the pollinators, and natural enemies, enlisting the major living organism providing agro-ecosystem services and recommend the best conservation and management package of practices for agro-ecosystem services).
- Develop site wise GIS maps and land cover/land escape maps showing the degree of climate change effect on agro-ecosystem services.
- Study on soil carbon, soil moisture availability and soil nutrient balance, soil humus and recommend the soil health improvement and management practices for restoration of agro-ecosystem services on Apple, Mustard, Buckwheat, Citrus etc.
- Coordinator, Experts, and Recruitment of District Agro-ecosystem Extension Workers (3), each in Dang, Mustang and Gulmi.
- Presentation of the results on result sharing workshop with concern stakeholders

Activity-1: Baseline study of the agroecosystem services based on the farmers perception survey (FPS)

Farmer perception survey and Focus group discussion (FGD), KII was carried out in the three project districts-Dang, Gulmi and Mustang which are the major commercial mustard, citrus and apple farming districts. Altogether 300 households (120 each in Dang & Gulmi, and 60 in Mustang) were selected using purposive random sampling techniques to carry out the baseline survey on the agroecosystem services. Data were collected by face-to-face interviews for which survey questionnaire was prepared, covering the demographic details of farms, farm management practices and perceptions of ES, pre-tested and finally improved incorporating suggestions from the concerned representatives- FAO and Government of Nepal. Each farmer was asked about the knowledge, importance of the AES abd to rank the importance on the basis of degree of importacne of the identified AES.. The summary of findings are: i) Over 2/3rd of the respondents (68%) are not aware of the concept of ecosystem services and around 90% of the respondents perceived the climate change is affectin the AES, ii) None of the respondents are using bio-pest control measures in the project districts, due to lack of their knowledge and support services, and iii) Among many drivers of ecosystem deterioration, climate change is one of the main drivers causing deterioration in every aspects of an ecosystem services, i.e. increasing pest incidence, habitat destruction and change in farming practices, pollinators decline etc. The findings have been concluded with major recommendations (***Refer Baseline Report***)

Activity-2: Preparation of the bibliographic databases, good management practices and the national policies and strategies related to the agroecosystem services in Nepal

1. Bibliography database
The bibliography compilation enlists the relevant literature in project mandated crops like apple, citrus, maize, rapeseed, and cucurbits with respect to eco-friendly cultivation practices of these crops and without disturbing ecosystem services. It compiles over 225 references of national significance, ecosystem services with farm benefits, importance of soil nutrients, beneficial organisms (predators, parasites, pollinators) and some botanicals having pesticide values in pest management are abstracted (***Refer Ecosystem Service Report***)

2. Good management practices
Apple**:** High hill region is well known for commercial cultivation of apple. It is cultivated in Jumla, Mugu, Kalikot Mustang, and part of Rasuawa, Sindhupalchok, Dolakha, Solukhumbu, Rukum, Rolpa. *Soil fertility*: In the apple growers' fields, soil tests for pH, organic matter, NPK and maintaining soil fertility is essential. *Nursery and orchard management:* Nursery soil and site should be free from insect pests and disease, and planting materials purchased from reliable source/registered nursery. Similarly, orchard management includes intercropping, mulching, fertilization and pest management practices in eco-friendly way, such as use of FYM with *Trichoderma* 1.5 kg in 50 kg of FYM and apply fortified FYM compost to each matured trees helps minimize root rot disease of apple. For insect pest management, spray of Servo oil @10 ml /l of water or Neem based pesticide@3-5 ml/l of water and use of Bt. @ 2gm/l of water at 7 days interval is suggested. During the flowering period honeybees are important for assured pollination of crops (FAO, 2014). Starting from soil preparation to post harvest necessary technical information outlined (***Refer Production Technology Report*****)**.

Citrus**:** Citrus is cultivated in mid hill region of Nepal. *Soil fertility*: like in apple, citrus growers' fields needs soil tests for pH, organic matter, NPK and maintaining soil fertility. *Nursery and orchard management:* Nursery soil and site should be free from insect pests and disease, and planting materials purchased from reliable source/registered nursery. Fertilizer application is adjusted according to the soil test results. Growing legume crops as intercropping helps improve soil fertility, as well as trap crops for insect pests and cover crop for moisture retention. Drenching / pasting/ foliar spray with 1% Bordeaux mixture/paste/spray suppress diseases. *Citrus psylla* transmits citrus greening disease. Bioagents like, predators like ladybeetles, syrphid fly help suppress pest problems. For fruit fly management protein baits and lures are effective when practiced in area wide basis. During the flowering period honeybees are important for assured pollination of crops. Spraying microbial consortium (Bio-fit) @ 1g /l or spraying *Ampelomyces quisqualis* (Powdery Care) @ 0.6g /l water protects cucurbits from mildew diseases (FAO, 2014). Starting from soil preparation to post harvest necessary technical information outlined (***Refer Production Technology Report*****).**

Rapeseed**:** Rapeseed is one of the most important cruciferous oilseed crops in the world and it is the major oil extracting crop in Nepal. *Soil fertility*: Fertile sandy loam to clay loam soil with 6-8 pH is suitable. Well decomposed FYM 10 mt/ha 20-25 days before seed sowing with 60: 40: 20 kg NPK/ha, half dose of N and full dose of PK as basal, and remaining N after 20-25 days with first irrigation. Selected varieties are: Moran Tori-2, Preeti, Unnati, Pragati, Bikash, T-9, JY-16.F1 etc. Sulfur 20 (Sulfur dust) and boron 10 (Borex) per ha, and if soil deficient in zinc adding 10 kg zinc sulfate is recommended. Using *Trichoderma harzanium, T. virens, Streptomyces arabicus* as biocontrol of diseases & prasitoids *Aphelinus*, predators ladybird beetle, lacewing, syrphid flies for soft insect pests. Starting from soil preparation to post harvest necessary technical information outlined (***Refer Production Technology Report*****).**

3. National policies and strategies
First five year plan in 1956, identified agriculture as one of the top priority sectors for development. However, only after the Fifth five year plan (1975-80), agriculture has been given top priority. Two dozens of national policy documents are reviewed and outlined in the document. There are still many problems to be addressed for eco-friendly crop production and food security in the context of climate change which needs due consideration in the national plans and policies (***Refer National Policies and Strategies Report*****)**

Activity-3: Field survey of pollinators, natural enemies and beneficial microorganisms

Pollination is essential for agricultural production, agro-ecosystem diversity and biodiversity. So, periodically, fields were visited in Dang (Mustard farming), Gulmi (Citrus orchards) and Mustang (Apple orchards); Pan traps were also installed in the fields during crop flowering stages to collect insect flower visitors and some important pests as well. A total of the four quadrant of 1*1 m^2 was established within the 50m * 25m areas plot on each site to assess the study of the predators and parasites on the mustard crops. The study was carried in weekly internal after the onset of the flower in the mustard & similarly followed in citrus & apple orchards. Collected insects were killed immediately in ethyl acetate, pinned and dried specimens were preserved in collection boxes. Important flower visitors were identified using insect keys and comparing with reference specimens. The major predators and parasites namely, lady bird beetle, ground beetle, syrphid flies, tiger beetle, tachinid flies, spider, mustard sawfly, ants, wasps, earthworm and painted bug was assessed. Over 75% of world's most commonly cultivated crops and 80% of all flowering plant species rely on animal pollinators, mostly insects, for pollination. Bees are the most important pollinators. Pollinators support an estimated 35% of food produced worldwide. Some flies, beetles, butterflies and moths are also good pollinators. So it is important to maintain habitat, use pollinator friendly plants in peripheral areas such as field edges, fencerows, hedgerows, road edges etc. and practice eco-friendly pest control measures (***Refer Monitoring Flower Visitors Report*)**.

Activity-4: Preparation of the land use map and the mapping of the pollinators and others beneficial organisms

GIS have covered wide range of applications in the fields of agriculture, environments, and integrated eco-environment assessment, which help in development and decision process. The GIS maps was prepared based on the land use patterns such as forest, shrub land, grassland, agriculture land, barren area, water body and snow/glacier etc. Agriculture lands cover 0.29-3.74% in Mustang, 43.74-70.19% in Gulmi and 52% in Dang project districts. Similarly, area and percentage coverage under different categories are tabulated for three project districts (***Refer GIS Map of Project Districts*)**

Activity-5: Soil nutrients status and soil microorganisms

1. Soil nutrients

Soil is an integrated components of an ecosystem (croplands, pasturelands, woodlands etc.) as a precious assets of nature for all life on earth, and before cultivation, it is necessary to check the soil for its nutrients. Therefore, semi-structured questionnaire was prepared, shared with FAO office for suggestion and improvement, and face – to – face interview was administered among randomly selected farmers in Dang (68 farmers), Gulmi (54 farmers) and Marpha (22 farmers). Soil samples were also collected following soil testing standards from farmers' fields as representatives of the selected areas, kept in cloth bags, well labeled, brought in Soil Testing Laboratory in Pokhara, Kaski. Soil analysis was done for major primary nutrients N, P, K, including soil pH and organic carbon. Soil pH is the measure of the acidity or basicity in soils, which affects the availability of plant nutrients. The findings are: i) pH testing indicated acidic in nature in Dang (mustard fields), moderately acidic to neutral in Gulmi (citrus orchards) and neutral to basic in Marpha (apple orchards), ii) Over 80% samples showed medium level of OM in Dang, very low to low in Gulmi, and low to very high in Marpha, respectively, iii) N was low-high in Dang, low-medium in Gulmi and low- high in Marpha, iv) Half to nearly all soil samples had low P in Dang, very low-very high in Gulmi and low-high in Marpha. Almost all samples had high P in Dang, low to very high in Gulmi & Marpha. Soil fertility management strategies have been presented (***Refer Soil Fertility Report*)**.

2. Soil microorganisms

Ten fields were selected from each districts randomly representing all the project sites and altogether 30 soil samples were collected from Dang, Gulmi and Mustang, collected samples kept in plastic bags, well labeled, brought in Laboratory for analysis. The plate-count technique (modified dilution-plate method as described by Johnson and Curl (1972) was used for determining numbers of *Trichoderma*, *Azotobacter* and *Actinomycetes*. Only *Azotobacter* and *Actinomycetes* were commonly detected in the 10^{-4} diluted solution in Dang (Mustard farming), Gulmi (Citrus orchards) and Mustang (Apple orchards) while *Trichoderma* occurred on in 4 samples out of 10 soil samples in Dang district. The soil biota includes vast numbers of microorganisms that naturally reside in soil and perform a wide range of functions which are essential for a normal and healthy soils, for which role of microorganisms and their used have been presented. (***Refer Soil Micro-organisms Report*)**

Activity-6: Information sharing

The technical support on strengthening agro-ecosystems resilience for climate change adaptation to improve food and nutrition security was implemented and information gathered from field situations in three project districts in the midst of the challenges posed by the onset of COVID-19 pandemics. Because of time-to-time lockdown due to pandemics, field movements were restricted which affected field activities and information gathering during crop growing seasons. However, in close coordination with all stakeholders, necessary activities were performed, no cost time extension was approved, necessary reports prepared and shared with FAO, University, Government and concerned stakeholders. Final information sharing meeting (gathering) was also decided in consultation with concerned stakeholders to share findings of the study (***Refer progress and technical Reports*)**.

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CHAPTER 1

1.1 Introduction

Biodiversity is the basis of humankind's existence and the foundation of human civilization. Nepal is known for its diversity of flora and fauna (Joshi et al., 2017). Nepal possesses only 0.1 percent of the total landmass of the world, but harbors about 2.7 percent of flowering plant species, i.e. in the 10th position in terms of flowering plant diversity in Asia and the 31st on a world scale. The diverse plants and animal species and life forms play a very important role in agriculture, i.e. various elements interplaying together. Flowering plants need pollination for seed formation. The cross pollination can happen through abiotic and biotic factors. The abiotic factors include wind, water and gravity. The biotic factor affecting the pollination ranges from vertebrates (e.g., bats) and invertebrates such as insects. The insects provide 80% of the total pollination and more than 85% of the animal pollination in crops, of which bees are the main pollinators (Pokharel, 2009), and other include moths, flies, wasps, beetles and butterflies. Only about 15 percent of the world's crops are pollinated by managed bee species, i.e. *A. mellifera*, *Apis cerana* and *Bombus* spp., while the rest are pollinated by un-managed solitary bees and other wildlife. Bees in general (*Apis* and Non-*Apis* bees) play an important role in the pollination of a wide range of crops and wild plants. The production of about 80% of the 264 crop species cultivated in the EU depends directly on insect pollinators, mostly bees. The global annual monetary value of pollination is estimated to be many hundreds of millions of dollars (about US$ 200 billion in 2012).

In addition to pollination services, bees contribute to other ecosystem services such as: food (i.e. honey, pollen, wax for food processing, propolis in food technology, royal jelly as a dietary supplement and ingredient in food); genetic resources (i.e. biodiversity, including rare and endangered species requiring protection), and cultural services (i.e. education, recreation and aesthetic values), all contribute to human welfare and wellbeing. Beside crop pollinators, other beneficial organisms are: predators, parasites, pathogens, earthworms, scavengers and detrivores. They play important roles on ecosystem services, while others are important pests in agro-ecosystem, forests and pastures. There seems complex web of threats: exposure to pesticide, loss of foraging habitats, and changes in landscapes and resulting pressure on beneficial organisms and much more complexities remain to be understood for their conservation.

The smallholder farmers are lack of knowledge and information on the problems on agro-ecosystem practices. It is difficult for them to identify the key drivers and barriers (climate related and human interventions coupled by use of improper agricultural practices such as imprudent use of agro-chemicals, slash burning, mono-cropping, flooding irrigation, etc.) that are contributing to the deterioration of essential elements of agro-ecosystem services that eventually affecting sustainability of agriculture production. In one hand, climate change effect and abuse of chemical fertilizers and pesticides are affecting diversity of natural enemies and crop pollinators resulting in failure of natural control and crop pollination services. On the other, the climate change causes the reduction in the availability of food and forage (pest, pollen & nectar and the organic matter), lacking suitable habitat for shelter and breeding, inter/intra species competition, higher pesticide risks with pest resurgence and outbreak have increasingly threatened the agro-ecosystem services. The stated problems are increasing year after years and the small and marginal farmers are directly and truly affected. The coping ability of these farmers are limited and constrained by lack of knowhow as a result inhibiting their efforts to raise productivity and production ultimately impacting on their household's level food and nutrition security.

The technical support through the project to the Government of Nepal is addressing present challenges related to: i) conserving biodiversity and population of natural enemies, pollinators, decomposers and symbiotic agents; ii) attaining sustainable agriculture and increasing crop yield and farm income through restoration of agro-ecosystem services; and iii) enhancing food security and livelihood of smallholders farmers. Besides, the good management practices developed by the project can contribute to ecological resilience against climate change extremes and environmental degradation.

The proposed project especially aims to achieve sustainability in the social, economic, institutional, and environmental aspects. The interventions are expected to bring sustainable working conditions and social protection through offering diversification in agricultural activities and integration of the different agro-ecosystem services through conservation of natural enemies, pollinators and other beneficial organisms for food security.

In this project, innovative practices and technologies are piloted, tested or scaled up by producers, to sustainably increase productivity, address climate change and environmental degradation. The project mainly contributes to one of the Regional Initiatives/ Priority Areas: Natural Resources management and Climate Change. In addition, this TCP also contributed to the Regional Initiative on Zero Hunger Challenge.

1.2 Project Objectives

General Objective

The general objective of the study is the strengthening of agro-ecosystems resilience for climate change adaptation and improving ecosystem services for sustainable crop production to ensure food and nutrition security.

Specific Objectives

The specific objectives of the proposed study are as follows.

- Carry out baseline survey (farmers perception survey) and prepare base line data on agro-ecosystem services in the selected agro-ecosystems,

- Desk reviews to prepare bibliographic databases and recommend the good conservation, and management package of practices for agro-ecosystem services on Apple, Mustard, Buckwheat, Citrus for the selected agro-ecosystem,
- Crop field survey and sampling (sampling, collection and preservation of the samples of the pollinators, and natural enemies, enlisting the major living organism providing agro-ecosystem services and recommend the best conservation and management package of practices for agro-ecosystem services).
- Develop site wise GIS maps and land cover/land escape maps showing the degree of climate change effect on agro-ecosystem services.
- Study on soil carbon, soil moisture availability and soil nutrient balance, soil humus and recommend the soil health improvement and management practices for restoration of agro-ecosystem services on Apple, Mustard, Buckwheat, Citrus etc.
- Coordinator, Experts, and Recruitment of District Agro-ecosystem Extension Workers (3), each in Dang, Mustang and Gulmi.
- Presentation of the results on result sharing workshop with concern stakeholders

1.3 Organization of the report

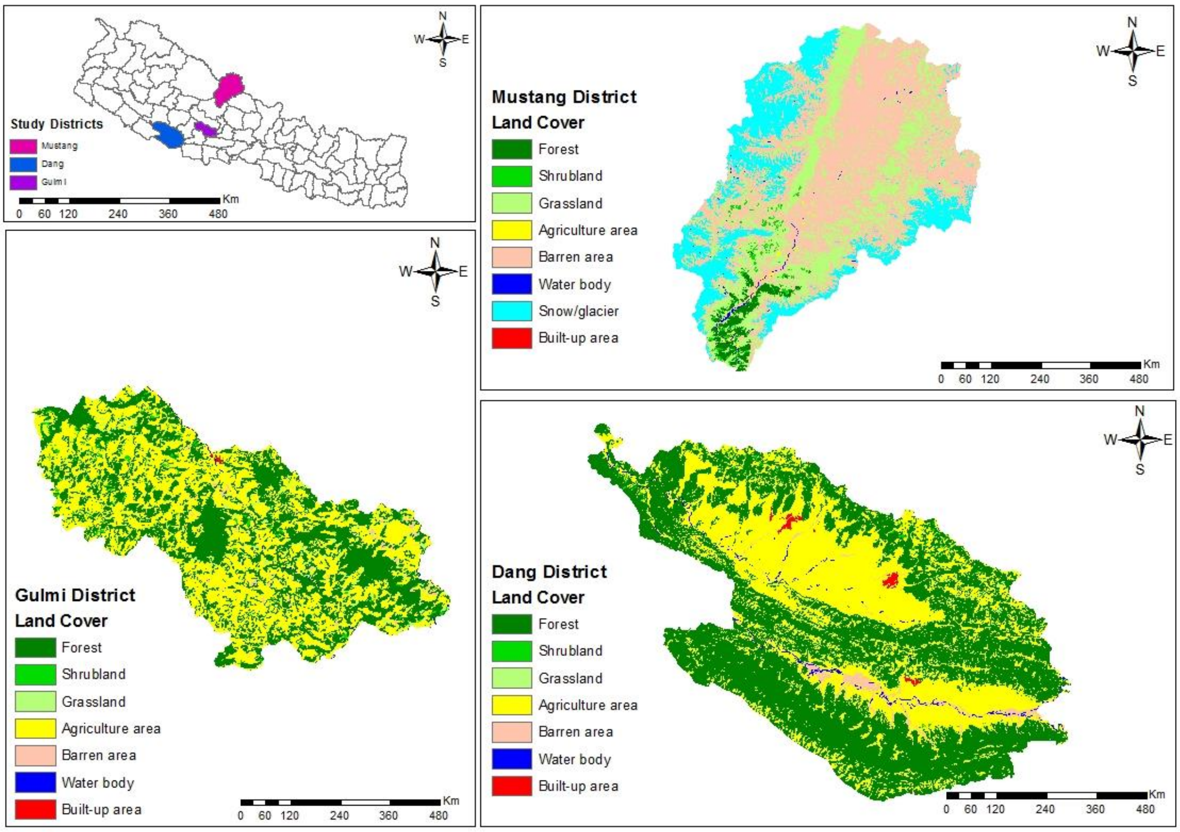
The report contains six chapters plus references and appendixes. The first chapter describes the background, objective and limitation of this study. The second chapter presents activity-1: baseline study of the agroecosystem services based on the farmers perception survey (FPS). The chapter-3 describes the activity-2: preparation of the bibliographic databases, good management practices and the national policies and strategies realted to the agroecosystem services in Nepal. The fourth chapter illustrates the activity-3: field survey of the pollinators, natural enemies and benefical microorganism available in the study areas. The fifth chapter highlights activity-4, preparation of the land use map and the mapping of the pollinators and others beneficial organism available in the study areas. The chapter -6: empahsizes the study of soil nutritents status and soil microorganism presents in the soil of the study areas.

1.4 Limitation of this study

This study focuses mainly on study of farmer's perception on agroecosystem services, pollinators and natural enemies and soil nutrients status on the three major crops- Mustard, Citrus and Apple in the study districts: Dang, Gulmi and Mustang, respectively. The report does not cover whole districts, as the study was carried just in three sites of each district. Despite of the many more challenges, COVID 19 hampered internal movements and implementation of field activities severly.

1.5 Study area

The research activites was carried out in the three disticts namely: Dang, Gulmi and Mustang representing the terai (tropical), hill (subtropical) and mountain (temperate) regions as shown below in the map of Nepal.



Map of Nepal showing the project districts- Dang, Gulmi and Mustang, Nepal

Dang district

Dang district is an inner Terai district of Nepal, located between 82^0 2´ and 82^0 5´E longitudes and 28^0 29´ and 28^0 36´ N latitudes and covers an area of 2902.510 square kilometers, with an elevation ranging from 213 to 2058 m above sea level. It is accessible from the east-west highway, and numerous feeder roads connecting the villages to the town. The total human population of the district is 552583 (CBS, 2012). The annual precipitation varies from 1584 to 2287 mm with an annual mean of 1830 mm. The study area enjoys nearly tropical and subtropical climate. Forests cover over 50% of the area while the remaining area falls under agriculture, water body and others. Dang district is geographically divided into two parts: Siwalik-hills and the plain valley or Bhabar. It is bound by the Mahabharat hills on the north and outer Siwalik hills on the south. The soil in the hills is loosely bound coarse sand, gravel and conglomerates while it is clay and sandy loam in Dang and Deukhari valley.

Gulmi district

Gulmi is a hilly district that lies in Lumbini Province, located between 83^0 17´ and 36^0 24´E longitudes and 28^0 5´ and 20^0 04´ N latitudes and covers an area of 1,149 km^2 (444 m^2), with population of 296,654 in 2001 and 280,160 in 2011. It is surrounded by Syangja and Parbat district on the east, Palpa, and Arghakhanchi on the south, Baglung on the north, and Pyuthan on the west. The district is famous for coffee and orange farming. It is major citrus producing area of Nepal with altitude ranging from 1000-2000, mean annual temperature being 17-20^0C and annual rainfall ranging from 1000-2800 mm. More than 10 Crore worth of orange is sold annually, which includes export to India.

Mustang district

Mustang is a himalayan district which lies at Northern-west part of Gandaki province and inside Dhaulagiri zone. Headquarter of this district lies at Jomsom. According to present political map, it has five rural municipalities viz. Thasang, Gharapjhong, Baragung Muktikshetra, Loghekar Damodar Kunda and Lomanthang rural municipality. Towards north, it has boarder to Republic China, towards west it has Dolpa district, towards east it has Manang district and towards south it has Myagdi district as its boarder. Its altitude ranges from minimum 2000 masl at Paihro Thapla, Kunjo to maximum 8167 meter at Dhaulagiri Mountain.

Ecologically, Mustang has been divided into three ecological zones. The areas from Jomsom to the southern lower parts, ranging the altitude from 2000masl to 3000masl, have majority of **temperate climate**. Next, from Jomsom to northern territories, altitude ranging from 3000masl to 4500masl, it has **alpine** type of climate and the remaining parts above 4500masl where snow is covered majority of time over the year have **tundra** type of climate.

The active vegetation period in the district is from the month of March up to October. The total area of Mustang is 363958 ha, approximately 3639.58 ha is cultivable land and around 2892.63 ha land is cultivated. Approximately, 2499 ha land is irrigated and the area covered with pasture land 147679 ha Mustang is sometimes known as the capital of apple in Nepal. Approximately 1200 ha land is considered suitable for apple cultivation and farmers have been actively growing this fruit. Naked barley, wheat and buckwheat are grown in terraced farms, while vegetables and fruits are grown in orchards. The population of the world is ever-increasing and it is projected to exceed 9 billion by 2050.

CHAPTER 2

Activity-1: Baseline Survey

2.1 Introduction

About one-third of the earth's surface has been used for agricultural production to meet the food demands of the growing world population (FAO, 2007). Though agricultural land is primarily used to produce crops and livestock for food, it also provides other services, such as fibre and biofuel production, opportunities to store carbon, on-farm biodiversity, and aesthetic and recreational opportunities. However, intensive agriculture often results in the loss of ecosystem services at both the farm and landscape scales. The agroecosystem services (AES) are vital to maintain and improve agricultural productivity in order to meet the food nutrition and security of a growing human population through sustainable crop production but many of these services are declining due to anthropogenic-driven ecosystems changes (Kennedy et al., 2013).

Before the 20th-century farmers were able to meet the food demands of the population without the use of chemical fertilizer and pesticides, they managed the diverse ecosystem services for agricultural production (Sandhu, 2006). Agriculture constitutes the largest ecosystem services which increased production of agricultural goods which resulted in significant impacts on human health and well-being (Foley et al., 2005). Conserving both ecosystems and their services is critical for economic development and poverty alleviation, as the livelihood and wellbeing of many people depend on biodiversity and ecosystem services (Sandhu et al., 2014). Biodiversity is essential for the provision of many ecosystem services that are important for human well-being.

The agroecosystem services can be classified into four main categories: provisioning, supporting, cultural, and regulating services (MA, 2005). Agricultural activities are leading to environmental destruction and loss of ecosystem services (ES) leading to a decline in biodiversity and threatening the environment (Tilman et al., 2001, Sandhu et al., 2010). It leads to the loss of the supply of other ecosystem services, such as the maintenance of soil fertility, water quality, pest control, and pollination (Logsdon et al., 2015; Gonzalez et al., 2015).

The ecosystem management approach to agriculture without neglecting its linkages with other components of the system would sustain its development on a long-term basis or otherwise, any of the strategic development efforts may end up in failure. The impact of the farm-level management practices like the use of fertilizer and pesticides, cropping practices, and knowledge about the different ecosystem services has been well documented for the agroecosystem ecosystem services management.

Investigating local people's perception of ecosystem services can more easily differentiate single provisioning, regulating, cultural and supporting services, which are often supplied in multiple-service bundles, and this can be a useful tool for prioritizing ecosystem services.

Local farmers' perceptions of ecosystem services differ among different regions that appear to reflect differences in local knowledge and background (generated by practice and observations. In order to harmonize the interrelation between humans and nature and to establish sustainable agricultural landscape management, it is important to understand the local people's perceptions of various ES in different regions. However, only a few studies have addressed local people's identification or perception of ecosystem services and most studies center on a single or a few ecosystem services.

2.2 Materials and Methods

2.2.1 Site description

The baseline survey was carried out in the three project districts Dang, Gulmi and Mustang which are the major commercial mustard, citrus and apple cultivating districts of Nepal. In the Dang district, the mustard was cultivated in an area of 20,978 ha producing 22,401 mt with a productivity of 1.07 t/ha. In Gulmi district, citrus was cultivated in area 747 ha producing 5,501 mt with productivity of 10.98 t/ha. Similarly, in the Mustang district, apple was cultivated in an area of 445.0 ha producing 5727.0 mt with productivity of 12.9 t/ha (MOAD, 2018).

A list of farmers in the project districts was obtained from the Agriculture Knowledge Center (AKC), PMAMP zone office and local government bodies to select the farmer's field school (FFS) participants. The farmer's field school farmers' participants were the respondents to carry out the baseline survey.

2.2.2 Selection of sample respondents

Altogether 300 farmers were selected using purposive random sampling techniques as the respondents to carry out the baseline survey on the agroecosystem services. From the Dang and Gulmi districts, 240 respondents (120 from each district) mustard growing farmers and citrus growing respectively and in Mustang 60 respondents were selected as the respondents.

2.2.3 Sampling technique and methods of data collection

The data of this study were collected both from primary and secondary sources. The primary data were collected from a household questionnaire survey, FGD, key informant interviews, and field observations. The questions included in the questionnaire were both closed-ended and open-ended types. The questionnaire was administered from November to February 2019 in the Dang and Gulmi whereas in the Mustang due to climatic factors and later with COVID 19 situation survey was carried out in the November to December 2020. This period was chosen mainly because it is an ideal time when farmers have completed their harvesting activities. Hence, it is easy to interview the sample farm households and collect the required data. Secondary data were also collected from books, journals and internet sources.

Data were collected by face-to-face surveys of each selected farmer. A survey questionnaire was prepared, covering the demographic details of farms, farm management practices and perceptions of ES. Each farmer was asked to rank the importance of the listed ES. The rankings were on a score of 1-5, 1 being least important, 3 being moderately important and five being highly important for their farming.

2.3 Results

2.3.1 Sociodemographic characteristics

The mean age of the respondents was higher in Gulmi districts (51.5 yrs) followed by the Dang (44.17 yrs) with the least in the Mustang districts (43.31 yrs). Similarly, the average family size was found to be less than 5 persons in Dang and Mustang as compared to Gulmi around 6 persons. The average landholding of the farmers was found higher in Gulmi districts (26.32 kattha) followed by the Dang (20.34 kattha) and the least in the Mustang districts (13.55 kattha) as shown in Table 1.

Table 1. Mean age, family number and landholding of the respondents in project districts, Nepal

SN	Variables	Dang	Gulmi	Mustang	P-value
1.	Age (yrs)	44.176 (14.372)	51.579 (14.091)	43.317 (12.033)	
2.	Family	5.613 (2.376)	6.212 (2.763)	5.200 (2.448)	0.114
3.	Landholding (kattha)	20.349 (17.161)	26.325 (17.423)	13.550 (9.282)	< 0.001

* Figure in the parenthesis shows the standard deviation.

Sex and education status

In altogether, about 59% of respondents were male followed by female 41%. We found that around 32% of the respondents in Dang district were illiterate, followed by the secondary level (30%), primary (21%) and least having a university degree around 1%. In the case of Gulmi district, most of the farmers were literate (31.6%) and had secondary level degrees (31.6%) followed by primary level education (29.8%) and least illiterate (2.7%). Similarly, in Mustang district most of the farmers received the primary level education (36.7%) followed by secondary (20%), literate (15%), illiterate (8.3%) and least university degree (5%). The results revealed that the economically active population was higher in the Gulmi districts (4.07) followed by Dang districts (3.68) and least on mustang (3.05) as shown in Table 2.

Table 2. Education status and sex of the respondents in project districts, Nepal

SN	Variables	Dang	Gulmi	Mustang	Total	P-value
1.	Sex					
	Male	62 (52.1%)	71 (62.3%)	39 (65.0%)	172 (58.7%)	0.155
	Female	57 (47.9%)	43 (37.7%)	21 (35.0%)	121 (41.3%)	
2.	Education status					< 0.000
	Illiterate	39 (32.8%)	3 (2.7%)	5 (8.3%)	46 (16.0%)	
	Literate	7 (5.8%)	36 (31.6%)	9 (15.0%)	51 (17.7%)	
	Primary	25 (21.0%)	34 (29.8%)	22 (36.7%)	81 (27.6%)	
	Secondary	36 (30.3%)	36 (31.6%)	12 (20.0%)	84 (28.7%)	
	Higher Secondary	11 (9.2%)	5 (4.4%)	9 (15.0%)	25 (8.5%)	
	University	1 (0.8%)	0 (0.0%)	3 (5.0%)	4 (1.4%)	
3.	Economically active member					< 0.001
	0-15 years	1.370 (1.073)	1.368 (1.358)	1.317 (1.066)	1.358 (1.187)	
	16-60 years	3.689 (1.817)	4.079 (1.786)	3.050 (2.020)	3.710 (1.880)	
	Above 60	0.555 (0.831)	0.772 (0.960)	0.817 (0.792)	0.693 (0.880)	
4.	Income per year	331916.387 (312463.23)	237210.526 (325344.05)	308333.333 (586926.54)	290239.078 (389735.75)	

* Figure in the parenthesis shows the standard deviation for economically active member and percentage for rest of the variables

2.3.2 Income of the respondents from the targeted crops

Annual income from the agriculture crops in 3 districts; average income of respondents was 17587.395 (24808.280) in Dang from the targeted crops (mustard), whereas it was 141289.474 (143412.625) in Gulmi from citrus and 194916.667 (273601.981) in Mustang from apple, respectively. The result shows the mustard growing farmers receive less income from the mustard crops whereas the farmer's income from the citrus and the apple was quite satisfactory for sustaining.

2.3.3 Awareness on ecosystem services

The result shows that overall all-around 68% of the respondents were not aware of the concept of ecosystem services. Around 96% of the respondents from the Gulmi district are not aware of the ecosystem services followed by 51% in the Dang and 46.7 % in the Mustang district. Around 90% of the farmers from the study areas perceived there was a change in the ecosystem services. In all three districts, more than 85% of the respondents agreed with the change in agroecosystem services.

Table 3. Farmers' awareness on the concept of ecosystem services and changes in the ecosystem services in project districts, Nepal

SN	Variables	Dang	Gulmi	Mustang	Total	P-value
1.	Awareness on ecosystem services					
	Yes	58 (48.7%)	4 (3.5%)	32 (53.3%)	94 (32.1%)	< 0.001
	No	61 (51.3%)	110 (96.5%)	28 (46.7%)	199 (67.9%)	
2.	Change in ecosystem services					
	Yes	109 (91.6%)	99 (86.8%)	55 (91.7%)	263 (89.8%)	0.589
	No	10 (8.4%)	14 (12.3%)	5 (8.3%)	29 (9.9%)	

2.3.4 Importance of ecosystem services

The result shows that around 80% of the farmers don't know about the ecosystem services importance in the agriculture production in the Gulmi districts followed by 24% in the Dang and the least respondent farmers in Mustang districts. About 29% of respondents from Dang and 15% from the Gulmi reported that ecosystem services are not important for agriculture. Most of the around 90% respondents from Mustang and 45% from Dang revealed ecosystem services as important for agricultural production as shown in Figure 1.

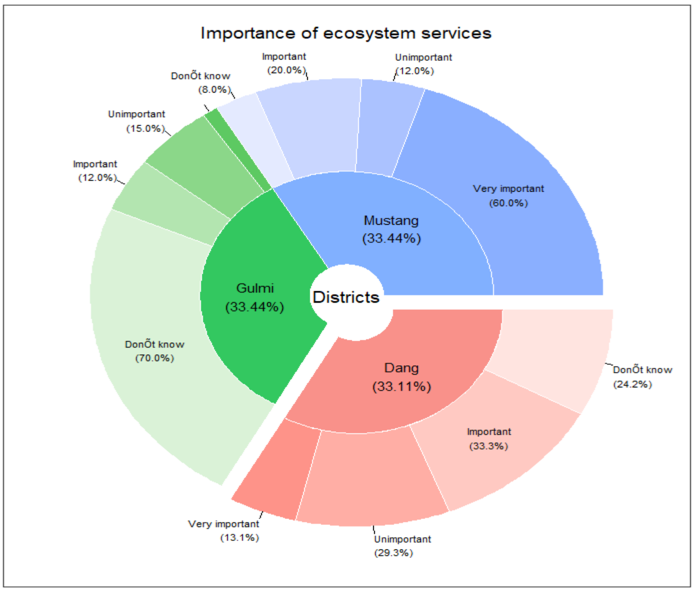


Figure 1. Farmers' perception on the importance of ecosystem services in project districts, Nepal

2.3.5 Knowledge on the different ecosystem services

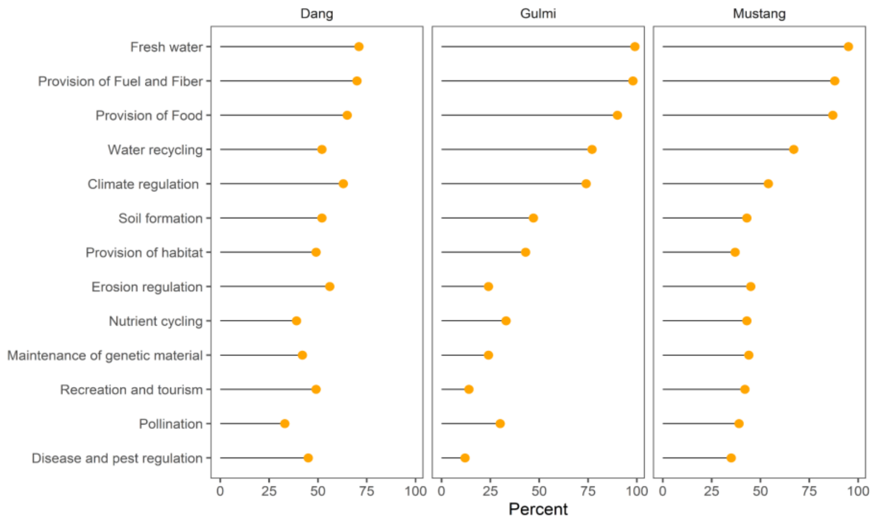


Figure 2. Farmers' knowledge on different identified ecosystem services in project districts, Nepal

2.3.6 Ranking of the importance of the ecosystem services

The result shows that the respondent's farmers perceived the ecosystem services more as the cultural services and provisioning services rather than the regulatory and supporting services as shown in Figure 3. This shows that the respondents were not aware of all the ecosystem services and their importance. The respondents rank the pollination, soil fertility, natural pest regulation less than the 3 scores mean, they perceive these ecosystem services as not so important for sustainable agriculture production.

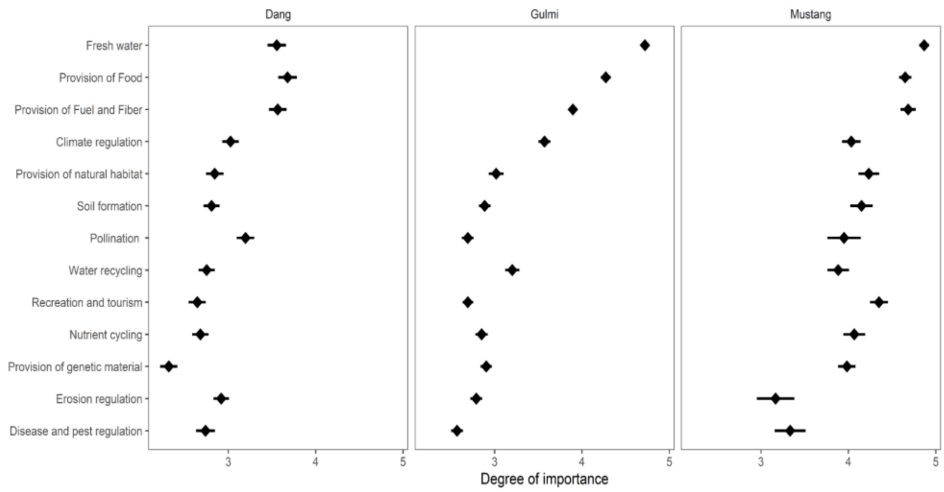


Figure 3. Farmers' perceptions on the importance of the ecosystem services in project districts, Nepal

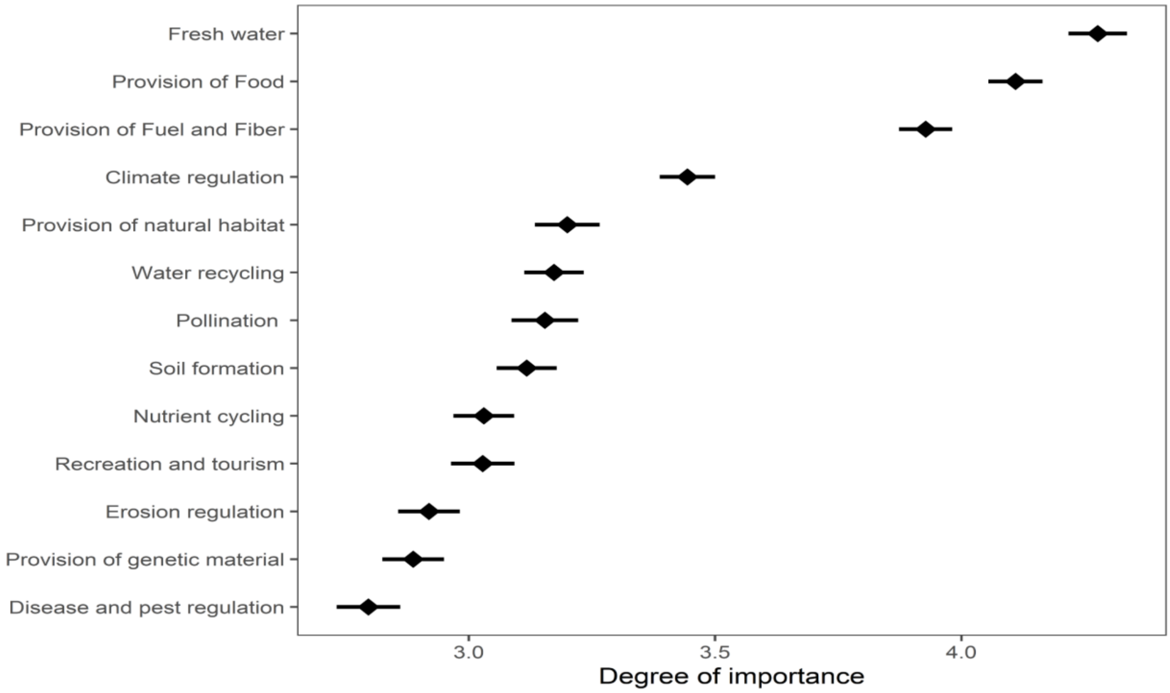


Figure 4. Farmers' perceptions on the importance of ecosystem services in project districts, Nepal

2.3.7 Agricultural practices adopted by the farmers

The results show the adoption of the agroecosystem-friendly practices by the respondents in the project districts as shown in Table 4. About 88% of the farmers and half of the farmers don't practice the crop rotation and mixed cropping respectively in Dang districts whereas in the Gulmi and Mustang 100% of the farmer's respondents adopted the crop rotation practices and mixed cropping. In the case of the kitchen garden practices, around 77% of the farmers in Dang district adopted this practice followed by 55% in the mustang and the least number of respondents (36%) adopted it in the Gulmi districts.

Table 4. Agriculture practices followed by the respondents in the project districts, Nepal

SN	Agricultural practices	Dang	Gulmi	Mustang	Total	P-value
1.	Crop rotation					
	Yes	14 (11.7%)	114 (100.0%)	60 (100.0%)	187 (64.1%)	< 0.001
	No	105 (88.2%)	0 (0.0%)	0 (0.0%)	105 (35.8%)	
2.	Mixed cropping					
	Yes	57 (47.9%)	114 (100.0%)	60 (100.0%)	231 (78.8%)	< 0.001
	No	62 (52.1%)	0 (0.0%)	0 (0.0%)	62 (21.2%)	
3.	Kitchen garden					
	Yes	92 (77.3%)	42 (36.8%)	33 (55.0%)	167 (57.0%)	< 0.001

	No	27 (22.7%)	72 (63.2%)	27 (45.0%)	126 (43.0%)	
4.	Contour farming					
	Yes	0 (0.0%)	25 (21.9%)	19 (31.7%)	44 (15.0%)	< 0.001
	No	119 (100.0%)	88 (77.2%)	41 (68.3%)	248 (84.6%)	
5.	Terrace farming					
	Yes	0 (0.0%)	100 (87.7%)	17 (28.3%)	117 (39.9%)	< 0.001
	No	119 (100.0%)	13 (11.4%)	43 (71.7%)	175 (59.7%)	
6.	Zero tillage					
	Yes	4 (3.4%)	7 (6.1%)	17 (28.3%)	28 (9.6%)	< 0.001
	No	115 (96.6%)	107 (93.9%)	43 (71.7%)	265 (90.4%)	
7.	Agroforestry					
	Yes	2 (1.7%)	108 (94.7%)	17 (28.3%)	127 (43.3%)	< 0.001
	No	117 (98.3%)	5 (4.4%)	43 (71.7%)	165 (56.3%)	
8.	Mulching					
	Yes	92 (77.3%)	2 (1.8%)	18 (30.0%)	112 (38.2%)	< 0.001
	No	27 (22.7%)	112 (98.2%)	42 (70.0%)	181 (61.8%)	

2.3.8 Drivers of change in ecosystem services

The use of chemical fertilizer, use of pesticides, loss of habitat and climate change are the major drivers which cause the change in the ecosystem services. The respondents from the Dang districts revealed that the use of chemical fertilizer followed by the use of pesticides, climate change are the major drivers of the change in the ecosystem services. Similarly, farmers respondents from the Gulmi district perceived climate change as the major factor followed by deforestation, erosion and landslides, loss of natural habitat with the least impact of pesticides that causes the change in the ecosystem services. In the case of the Mustang district, loss of natural habitat was a major driver followed by the use of chemical fertiliser, climate change, use of pesticides as shown in Figure 5.

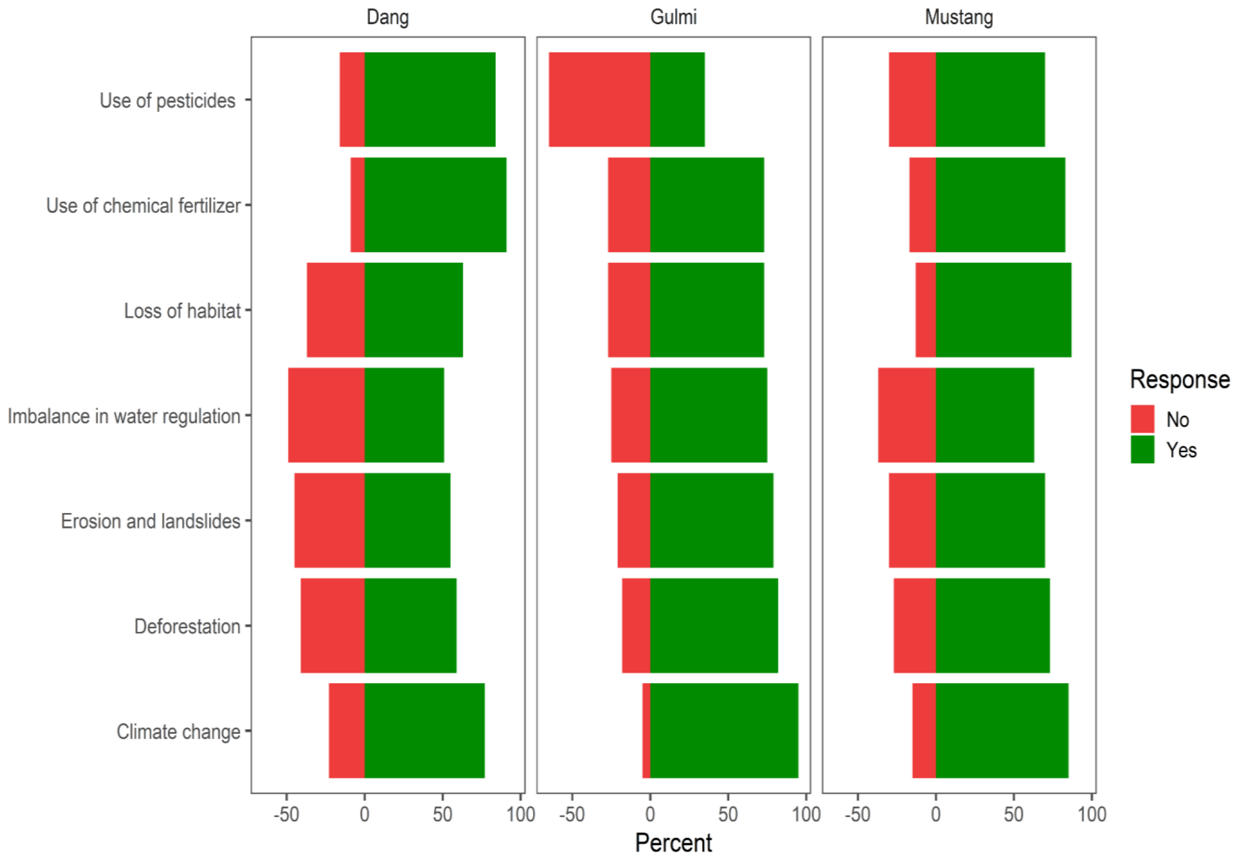


Figure 5. Farmers' perception on the drivers of the change in ecosystem services in project districts, Nepal

2.3.9 Ranking of the key drivers of change in ecosystem services

Table 5. Farmers' perceptions on the key drivers of change in ecosystem services in project districts, Nepal

Key drivers of change in ecosystem services	Dang	Gulmi	Mustang
Climate change	1.481 (0.853)	2.044 (0.309)	1.233 (0.500)
Use of pesticides	1.301 (0.789)	3.807 (0.578)	1.233 (0.563)
Deforestation	2.096 (0.730)	2.833 (0.459)	1.450 (0.790)
Imbalance in water regulation	2.246 (0.730)	2.772 (0.442)	1.783 (0.825)
Erosion and landslides	2.424 (1.447)	2.752 (0.454)	2.317 (1.000)
Use of chemical fertilizer	1.315 (0.757)	3.702 (0.547)	1.500 (0.834)
Loss of habitat	2.420 (0.907)	2.741 (0.533)	1.400 (0.588)

2.3.10 Source of information about the ecosystem services

The result showed that the overall information about the ecosystem services will be obtained from the friends (23.2%) followed by the self-experience 20.5%, agriculture extension staff (20.1%), Radio/TV/Internet (14%) and with the least from the farmer's field school (5.1%). The accessibility of the agriculture extension workers in Dang (36.1%) is very high as compared to the Gulmi (11.4%) and Mustang (5.0%) districts as shown in Table 6.

Table 6. Source of the information about the ecosystem services to the respondents in project districts, Nepal

SN	Source of information	Dang	Gulmi	Mustang	Total	P-value
1.	Agriculture extension staff	43 (36.1%)	13 (11.4%)	3 (5.0%)	59 (20.1%)	< 0.001
2.	Farmer field school	15 (12.6%)	0 (0.0%)	0 (0.0%)	15 (5.1%)	
3.	Radio/TV/Internet	13 (10.9%)	17 (14.9%)	11 (18.3%)	41 (14.0%)	
4.	Self-experience	14 (11.8%)	20 (17.5%)	26 (43.3%)	60 (20.5%)	
5.	Friends	27 (22.7%)	40 (35.1%)	7 (11.7%)	68 (23.2%)	
6.	Others	6 (5.0%)	24 (21.1%)	13 (21.7%)	43 (14.7%)	

2.3.11 Insect pest and disease incidence

The result showed that around 59% of the farmers from total perceived as the increase in the incidence of the insect pest and disease in the major crops grown in the project districts, showing that 87.4% of the respondent from the Dang and 46.7% of the respondents from the Mustang perceived increased whereas 59.6% of respondents in the Gulmi districts perceived no change in the incidence of insect pest and disease shown in Table 7.

Table 7. Farmers' perception on the incidence of insect pests and diseases on the targeted crops in project districts, Nepal

SN	Insect pest and disease incidence	Dang	Gulmi	Mustang	Total	P-value
1.	Decline	11 (9.2%)	0 (0.0%)	20 (33.3%)	31 (10.6%)	< 0.001
2.	No change	3 (2.5%)	68 (59.6%)	3 (5.0%)	74 (25.3%)	
3.	Increase	104 (87.4%)	41 (36.0%)	28 (46.7%)	173 (59.0%)	
4.	Don't know	1 (0.8%)	5 (4.4%)	9 (15.0%)	15 (5.1%)	

2.3.12 Reason to increase the incidence of insect pest and disease

The result showed that climate change is the major reason followed by the use of pesticides and the least is due to the loss of the ecosystem services as in Table 8.

Table 8. Reason for increase in the incidence of insect pests and diseases in project districts, Nepal

SN	Reason for the incidence of insect pest and disease	Dang	Gulmi	Mustang	Total	P-value
1.	Climate change	56 (47.1%)	28 (24.6%)	24 (40.0%)	108 (36.9%)	< 0.001
2.	Loss of ecosystem services	12 (10.0%)	23 (20.2%)	13 (21.7%)	47 (16.3%)	
3.	Use of pesticides	41 (34.5%)	23 (20.2%)	18 (30.0%)	82 (28.0%)	
4.	Don't know	9 (7.6%)	40 (35.1%)	5 (8.3%)	54 (18.4%)	

2.3.13 Trends of chemical pesticide use

Survey showed that about 50% of the farmers perceived as the increase in the use of chemical pesticide in the major crops grown in the project districts, showing that 80.7% of the respondent from the Dang and 50.5% of the respondents from the Mustang perceived increased whereas 79.8% of respondents in the Gulmi districts don't know about the trend of chemical pesticide use shown in Table 9.

Table 9. Farmers' perception on the trends of the chemical pesticide use in project districts, Nepal

SN	Trends of the chemical pesticide use	Dang	Gulmi	Mustang	Total	P-value
1.	Decline	6 (5.0%)	0 (0.0%)	7 (11.7%)	13 (4.4%)	< 0.001
2.	Increase	96 (80.7%)	16 (14.0%)	36 (60.0%)	148 (50.5%)	
3.	No change	5 (4.2%)	4 (3.5%)	15 (25.0%)	24 (8.2%)	
4.	Don't know	12 (10.1%)	91 (79.8%)	2 (3.3%)	103 (35.9%)	

2.3.14 Biocontrol agents

The result shows that overall, 94% of the respondents don't use the biocontrol agents in the project districts. Among, around 97.5% of the respondents from the Dang district don't use the biocontrol agents for the control of the insect pest and disease followed by 95.6% in the Gulmi and 85 % in the Mustang district as shown in Table 10. This showed that almost no farmers use biocontrol agents to control insect pests and diseases.

Table 10. Use of the biocontrol agents to control insect pests and diseases in project districts, Nepal

SN	Use of biocontrol agents	Dang	Gulmi	Mustang	Total	P-value
1.	No	116 (97.5%)	109 (95.6%)	51 (85.0%)	276 (94.2%)	< 0.001
2.	Yes	3 (2.5%)	5 (4.4%)	9 (15.0%)	17 (5.8%)	

2.3.15 Knowledge on pollination

The result shows that around 61% of the respondents don't have knowledge of pollination and pollinators in the study districts. Among them, around 77.2% of the respondents from the Gulmi district followed by 53.3% in the Mustang and 49.6 % in the Dang district don't have knowledge on the pollination and pollinators as shown in Table 11.

Table 11. Farmers' knowledge on the pollination and pollinators on the three project districts, Nepal

SN	Knowledge on pollination	Dang	Gulmi	Mustang	Total	P-value
1.	Yes	60 (50.4%)	26 (22.8%)	28 (46.7%)	114 (38.9%)	< 0.001
2.	No	59 (49.6%)	88 (77.2%)	32 (53.3%)	179 (61.1%)	

2.3.16 Status of pollinator population

Table 12 shows the trends of the pollinator population on the farmers' perception. The result shows that on aggregate more than 50% of the farmers perceived the decrease in pollinators' population. About 65% of the farmers in the Dang districts followed by 55% in Gulmi and at least 32% in Mustang reported the decline in the pollinator population. Similarly, total of 24% of farmers from the three districts perceived there is an increase in the pollination population followed by around 14% no change and 12% who don't know the status of the pollinator population.

Table 12. Farmers' perception on the trends of pollination population in project districts, Nepal

SN	Trends of pollinator population	Dang	Gulmi	Mustang	Total	P value
1.	Decline	77 (64.7%)	63 (55.3%)	19 (31.7%)	159 (50.56%)	< 0.001
2.	Don't know	1 (0.8%)	16 (14.0%)	12 (20.0%)	29 (11.6%)	
3.	Increase	36 (30.3%)	21 (18.4%)	14 (23.3%)	71 (24.0%)	
4.	No change	5 (4.2%)	14 (12.3%)	15 (25.0%)	34 (13.83%)	

2.4 Conclusion

The survey showed that 41% were female respondents and mean age of all the respondents was higher in Gulmi (51.5 yrs) followed by Dang (44.17 yrs) and Mustang (43.31 yrs) districts. The income of mustard growing farmers in Dang was lower (Rs 17587.39/yr) whereas the farmer's income from citrus (Rs 141289.47/yr) in Gulmi and apple (194916.67/yr) in Mustang was quite satisfactory.

Regarding farmers perception, over 2/3rd of the respondents (68%) were not aware of the concept of ecosystem services. They perceived the ecosystem services more as the cultural services and provisioning services rather than the regulatory and supporting services, as indicated by their rankings with less than 3 scores on pollination, soil fertility, and natural pest regulation services. Among the respondents 88% didn't practice crop rotation in Dang districts, while in Gulmi and Mustang all of them adopted the crop rotation and mixed cropping practices.

The survey revealed that the major drivers of changes in the ecosystem services were: use of chemical fertilizer followed by pesticides, climate change in Dang; similarly, climate change followed by deforestation, erosion and landslides, loss of natural habitat in Gulmi, and loss of natural habitat was a major driver followed by the use of chemical fertiliser, climate change, use of pesticides in Mustang, respectively. Among respondents, around 59% perceived increase in the incidence of the insect pest and disease in major crops grown in the project districts. Climate change seemed the main reason followed by the use of pesticides of pest increase as perceived by the farmers.

Around 50% of the farmers perceived the increase in the use of chemical pesticide in the major crops, while none of the farmers used any biocontrol agents to control pests and about 61% don't have knowledge of pollination and pollinators in the study districts. This finding indicates that on an aggregate more than 50% of the farmers perceived the decrease in pollinators' population in the project areas, which was districtwise higher in Dang (65%) followed by Gulmi (55%) and Mustang (32%).

2.5 Recommendation

This project addresses ecosystem sustainability and food security in the project districts. However, over 2/3rd of the respondents (68%) are not aware of the concept of ecosystem services. Training and FFS activities would help to bring better understanding and take care of an ecosystem services.

None of the respondents are using soil building and bio-pest control measures in the project districts, due to lack of their knowledge and support services, like access to eco-friendly materials in the local agrovets. GOA needs focusing crop production, productivity and food security as well with need based support services such as making availability of eco-friendly pest control mesures at the local level.

Climate change is one of the main drivers causing deterioration in every aspects of an ecosystem services, i.e. increasing pest incidence, habitat destruction and change in farming practices, pollinators decline etc. Research and developmental activities are necessary to solve such ever increasing problems.

CHAPTER 3

Activity-2: Bibliographic Databases on Agro-ecosystem Services

(Review national legislations, regulations, policies, plans and SoP in relation to agro-ecosystem services)

The age of modern agriculture in Nepal has been started with the establishment of the agriculture council and the construction Chandra Canal in 1937 with an attempt of institutionalizing development works in agriculture. However, desired changes were not obtained and after the formation of the democratic political system in 1951 foreign aid and agencies started to play a major role in the formulation of national policies and planning. After the implementation of the First Five Year Plan in 1956, agriculture was identified as one of the top priority sectors for development. Despite of this, only after the Fifth Five Year Plan (1975-80), agriculture has been given the top priority. Following are the plan and policies realted to the agroecosystem services

1. Constitution of Nepal, 2015 (2072)
2. National Agro-biodiversity Policy of Nepal, 2007 (2063)
3. National Agriculture Policy, 2004 (2061)
4. Rangeland Policy, 2012 (2068)
5. Land Use Policy, 2012 (2069)
6. Land Use Policy, 2015 (2072)
7. Climate Change Policy, 2011 (2067)
8. The Agriculture Perspective Plan, 1995-2015
9. Agriculture Development Strategy, 2015-35
10. Strategic Framework on Nature Conservation for Sustainable Development (NCNSFSD) (2015-2030)
11. National Biodiversity Strategy and Action Plan (NBSAP), 2014-2020
12. National Farmer's Commission, 2017
13. Irrigation Policy, 2016
14. Forestry Sector Policy, 2000
15. National Seed Policy, 2000
16. National Fertilizer Policy, 2002
17. National Standards of Organic Agriculture Production and Processing, 2007
18. Prime Minister Agriculture Modernization Project (PM-AMP), 2016
19. Zero Hunger Challenge National Action Plan, 2016–2025
20. The Local Government Operation Act (LGOA), 2017
21. Agri-Business Promotion Policy, 2006
22. Agriculture Bio-diversity policy, 2007

23. National Forestry Policy, 2018
24. National Climate Change Policy, 2019 (2076)

1. Constitution of Nepal, 2015 (2072)

The government of Nepal decided to transform Nepal into a federal, democratic and republican country through a new constitution in 2072. Following the election of all three levels, the Government has initiated the implementation of federalism through administrative restructuring and fiscal budgeting. After the introduction of the new constitution in Nepal, the unitary country has been restructured into 7 provinces securing the rights and responsibilities of all citizens. These provinces have been divided mostly on the geographic, socio-cultural and unique perspective of agriculture development taking care of biodiversity conservation by minimizing the negative impacts of industrialization and physical development. Province 2 has a mostly tropical climate, province 4 and 6 have a largely temperate climate and are less diverse, while Provinces 1, 3, 5 and 7 have both temperate and tropical climates and are more diverse in terms of agriculture crop production potentialities. These provinces will be interdependent to each other in terms of economic production, the surplus in certain commodities and deficit in others, thus enjoying inter-dependency for inputs and product markets and also with proper institution supports for carrying out such agriculture activities at the province level. Constitutionally agriculture is more state matters and it has also been the concurrent function of all central, state and local governments. Thus, the authority of agriculture extension lies with local and state while regulatory and policy strategies are through the central level.

2. National Agro-biodiversity Policy of Nepal, 2007 (2063)

The Agro-biodiversity Policy of Nepal has the vision to conserve and sustainable use of agricultural genetic resources/materials and associated traditional knowledge with the participation of concerned stakeholders for present and future generations. The policy recognizes agro-biodiversity as an integral component of biodiversity based on the spirit of international treaties/agreements and national initiatives in order to ensure social, economic and environmental benefits to the Nepalese people. Its objectives were-

- To enhance agricultural growth and ensure food security by conserving, promoting and sustainably using agro-biodiversity.
- To protect and promote the rights and welfare of the farming communities for their indigenous knowledge, skills and techniques (IKT).
- To develop options for a fair and equitable sharing of benefits arising from the access and use of agricultural genetic resources and materials.

- To create effective management, commercialization and use of agricultural genetic resources in the present context of exploiting local national and international markets and in international regulations on trade.
- To contribute to maintaining sustainable ecological balances (ecosystems services) over time.
- To promote the conservation and use of agro-biodiversity in the contexts of national seed, food quality and safety, and product marketing regulations
- To promote inter-ministerial, inter-sectoral consultation, problem identification and regulation development as far as agro-biodiversity is concerned.

3. National Agriculture Policy, 2004 (2061)

The National Agriculture Policy was formulated to create an enabling environment for agriculture-led rural development. It emphasizes the competitiveness of the agriculture sector encouraging farmers to go for commercial production. The policy aims at increasing productivity and promoting natural resources to utilize in the interest of farmers. The long-term vision of the agriculture sector is to bring improvement in the living standards through sustainable agricultural development by transforming the subsistence agricultural system into a commercial and competitive agricultural system. The policy emphasizes increased agricultural production and productivity, making agriculture competitive in regional and world markets with commercial agriculture systems, and conserving, promoting and utilizing natural resources, environment and bio-diversity. Its one of the weaknesses is draft of the land use policy has been developed but not implemented.

4. Rangeland Policy, 2012 (2068)

The Rangeland Policy was formulated to contribute to livelihood improvement and food security of the people, reduce internal migration and minimize the effects of climate change in the high hills and mid-hills regions where livestock farming is the major source of livelihood of people. For providing clear direction for managing uncontrolled extraction or harvesting of rangeland resources, like herbs and NTFPs, preventing the declining rangeland productivity and biodiversity due to uncontrolled grazing, minimizing the effects of climate change and environmental degradation, evaluating their roles in carbon sequestration, and promoting indigenous knowledge, skills, technologies, this policy was formulated and implemented, inter alia, recognizes the Department of Livestock Services as the lead agency for rangeland management, considers rangelands as under constant and serious threats, which require urgent attention, envisages sustainable use and development of natural rangeland with a view to supporting the livelihood of the local people and also about the development of livestock sector through sustained feed supply and grazing management.

5. National Land Use Policy, 2012 (2069)

To solve the situation of increasing fertile land fragmentation and unplanned urbanization this policy was formulated. The policy ensures the optimum use of land and control land fragmentation; establish a link between agricultural with industrial sectors, and encourage optimal use of land for agriculture. The policy categorizes the land into seven categories as agricultural, forest, residential, commercial, public, industrial, and others for the first time in the country. It ensures that fertile land is used for farming only, and bars dealings in land allocated for agriculture; and establishes the Land Use Management Department, which has experts from agriculture, irrigation, environment, urban development and management sector.

6. Land Use Policy, 2015 (2072)

After the devastating earthquake in the year 2015, this policy was formulated to manage the settlements safely from natural disasters. This realized the problem on the food security due to reduction of agriculture production and productivity because of increased use of fertile land for unproductive purposes, most of the lands under fallow and uncontrolled fragmentation. The soil erosion, floods, landslides and desertification due to environmental pollution and climate change causing to loss of natural resources, environmental degradation and loss of biodiversity and forests are of serious concern. The objectives of this policy are to ensure food security, increasing agricultural production and productivity through conservation and best utilization of agricultural land, and reducing climate change impacts, natural disasters, biodiversity and environmental conservation.

7. Climate Change Policy, 2011 (2067)

Nepal formulated a targets-based Climate Change Policy in 2011 to address the adverse impacts of climate change, by considering climate justice, through the pursuit of environmental conservation, human development, and sustainable development all contributing toward a prosperous society. The main objective of the policy is to improve livelihood by mitigating the adverse impacts of climate change, adapting to it, adopting low carbon emission, socio-economic development path and promoting the support and cooperation as per the commitments at the national and international mechanism related to climate change. The policy considers the importance of the sectors that are vulnerable to climate change, enhances the climate adaptation and resilience capacity of local communities for optimum utilization of natural resources and their efficient management, adopts the low carbon development path by making socio-economic development climate change friendly and resilient society. It emphasizes the establishment of a semiautonomous climate change center to coordinate the programs and projects, develop the capacity for identifying the present and future impacts of climate change, quantifying the impacts, adapting measures to be safe from the risks and adverse impacts of climate change, and establish a separate Climate Change Fund for implementing programs related to climate adaptation and resilience, and low-carbon development, identifying risks, carrying out studies/research, and developing and utilizing technologies.

8. The Agriculture Perspective Plan, 1995-2015

The Agriculture Perspective Plan is an important document for agriculture development in Nepal. The main objectives of the APP were to accelerate the growth rate in agriculture through increased factor productivity and it was emphasized on the technology-based green revolution in agriculture ensuring regional balance. Agro-biodiversity conservation was officially first included in the text of the Tenth Plan (2002-2007) which recognized that biodiversity is closely linked to livelihood and economic development. The objectives of the APP on the agrobiodiversity conservation were-

- To accelerate the growth rate in agriculture through increased factor productivity;
- To alleviate poverty and achieve significant improvement in the standard of living through accelerated growth and expanded employment opportunities;
- To transform subsistence-based farming to commercial agriculture through diversification and widespread realization of comparative advantage;
- To expand opportunities for overall economic transformation by fulfilling the precondition of agricultural development; and
- To identify immediate, short-term and long-term strategies for implementation and provide clear guidelines for preparing periodic plans and future programs.

9. Agriculture Development Strategy, 2015-35

This report covers the overall strategy for the Action Plan and Roadmap and a rationale based on the assessment of the current and past performance of the agricultural sector. The vision of the ADS are-

- Future trends affecting the agriculture sector in Nepal
- Agricultural transformation
- Agricultural labor force
- Change in diet
- Globalization and trade
- Outmigration
- Green technology and low carbon emissions
- Diversification
- Distribution systems

- Quality and safety
- Cost of energy
- Climate change, natural disaster and global crises management
- Degradation of natural resources
- Fiscal discipline

10. Strategic Framework on Nature Conservation for Sustainable Development (NCNSFSD) (2015-2030)

In 1980, the International Union for Conservation of Nature (IUCN) prepared and started implementing the World Conservation Strategy. Being a member state of IUCN, Nepal also formulated and enforced the National Conservation Strategy (NCS) in coordination with the National Planning Commission (NPC) in 1988. NCNSFSD is an umbrella strategy for the conservation of nature covering biodiversity, forest, water, air, land, cultural heritage as the continuation of NCS. It emphasizes nature conservation, sustainable use of natural resources and equitable distribution of their benefits; hence, it covers all other sectoral strategies related to nature conservation. The major dimensions among them are integrating environment conservation into physical infrastructure development and economic and social development programs, documenting biodiversity and indigenous knowledge and skills for conservation, promotion and sustainable use, promoting ecosystem services through scientific, inclusive and participatory management of forest heritage, establishing genetic and seed banks, and encouraging environment-friendly agricultural production.

11. National Biodiversity Strategy and Action Plan (NBSAP) 2014-2020

The Nepal National Biodiversity Strategy and Action Plan was designed to provide a strategic framework for the conservation and sustainable use of Nepal's biodiversity for enhancing local livelihoods and eco-friendly national development, and equitable sharing of the benefits accrued from the utilization of biological resources among all sections of the society. It is a multi-sectoral strategy and plan with national coverage and the country's response to its commitment under the Convention of Biological Diversity (CBD). The NBSAP highlights the importance of biodiversity for food security and nutrition and also seeks the improvement in the management of protected areas, forest biodiversity outside protected areas, rangeland biodiversity, wetland biodiversity, agro-biodiversity, and mountain biodiversity.

12. National Farmer's Commission, 2017

The National Farmers' Commission (NFC) has been formed as per the executive Order in 2016 with an objective to ensure and protect the rights of farmers in agriculture, food, land, social security and agro-biodiversity issued by the Government of Nepal (GoN) as envisioned by the Agriculture Development Strategy (2015-2035). The main goal of this commission is to develop agriculture as a dignified and attractive profession with the creation of peasants' rights friendly environment for guaranteeing peasants' rights by facilitating the implementation of their constitutionally assured rights in co-operation with the GoN, and concerned stakeholders. The peasants right is the access and right of producer farmers to resources and means of food and agricultural production, agricultural goods and natural resources, rights to food sovereignty, rights to agricultural production, market and market price, rights on indigenous and gained knowledge, skill and technology, indigenous crop varieties, seeds, breed, varieties and breeds developed by farmers, rights to research, subsidies, relief, insurance, extension services and facilities, and farmers social security, right of participation of farmers in policy-making level, and right to social justice.

13. Irrigation Policy, 2016

The Irrigation Policy, 2060 has been drafted on the basis of the achievement and experience, towards implementation of Irrigation Policy, 2049 (First Amendment, 2053). The objectives of the Tenth Five Year Plan and the principle was incorporated in the Water Resources Strategy. The major goal of the policy was to be able to provide year-round irrigation facility with effective utilization of existing resources, to develop the institutional capacity of water users for sustainable management of existing systems and to improve potential of the technical human resources, water users and NGOs related to the development of irrigation sector. However, identification, zoning and declaration of irrigable areas for agricultural purposes are not initiated.

14. Forestry Sector Policy, 2000

An increase in the population has created higher pressure on the forest. To reduce the pressure on the Terai, the Churia hills and the Inner Terai forest, the policy provided explicit management options for the forests. It has also given recognition to the Agricultural Perspective Plan (APP), Master Plan for the Forestry Sector (MPFS), and the Nepal Environmental Policy and Action Plan (NEPAP), all of which pay special attention to the management forests in the hills and the Siwaliks. The National Biodiversity Action Plan provides a broad framework for developing a comprehensive work plan for forests, Protected Area System (PAS), wetlands, mountains and agriculture. During the Ninth Year Plan, the forestry sector policy was formulated with the objective of agricultural growth and food production. The main objectives are to mobilize, conserve and manage forest resources to reduce the gap between demand and supply, create income-generating and employment opportunities for poor and marginal families, mobilize local people to enhance productivity and adopt proper land-use practices.

15. National Seed Policy, 2000

The government of Nepal formulated National Seed Policy considering seven aspects for the growth of the seed industry-

- Variety development and maintenance
- Seed multiplication
- Quality control
- Increased involvement of private sector
- Seed supply
- Institutional strengthening and
- Biotechnology

The National Seed Policy has the following objectives-

- Availing quality seeds of various crops in required quantity
- Promoting export by producing quality seeds
- Making seed business effective in existing world trade
- Conserving indigenous genetic resources and coordinating with concerned organizations to ensure national rights of the resources.

However, the availability of quality seeds of different varieties of cereals and vegetables is still the main problem.

16. National Fertilizer Policy, 2002

The fertilizer policy is a sub-component of the government's initiative namely the National Agriculture Policy as set out in the Agriculture Perspective Plan. The main aim of the National Fertilizer Policy is to support agricultural production by ensuring production, import and distribution of fertilizers. Eventually, the goal is to improve soil fertility which would result in improvement of agricultural productivity and ultimately alleviate poverty. This policy aims at making sure that fertilizers are available, the process of fertilizer distribution remains effective, competitive and transparent, quality fertilizers are used and the Integrated Plan of Nutrients System is maintained. However, fertilizer availability in terms of quality, quantity, and in time is not ensured, and the pricing policy implemented by the government is contrary to the fertilizer policy.

17. National Standards of Organic Agriculture Production and Processing, 2007

As the relationship between agriculture and the environment has been recognized, some policy statements to reduce the detrimental effects of agriculture on the environment have been undertaken ever since the Seventh Plan. The 10th Plan (NPC, 2003) and National Agricultural Policy (MOAC, 2004) have, for the first time, spelled out policy statements regarding the promotion of organic farming in the country. The policy documents have adopted one of their objectives as to conserve, promote and utilize natural resources, environment and biodiversity, which vaguely infers to a kind of state emphasis laid on the development of organic agriculture. In this regard, the state has enacted National Standards of Organic Agriculture Production and Processing, 2064. This policy has the following objectives-

- Specifies land arrangement for organic production,
- Prohibits agro-chemicals contamination in crop production and product transfer and storage,
- Use of inorganic feeds, GMOs/LMOs and radioactive devices and burning of organic wastes,
- Limits the use of fertilizers, undecomposed and poultry manure and town-compost,
- Emphasizes using local-variety,
- Organic seed source and no chemical seed treatment technique,
- Avoids torturous raring of animals, fetal implantation, cloning and hormonal use in animal production
- Limits artificial insemination in livestock as well as fish production
- Protects farmers for fair remuneration from their produces, and employees, children, consumers and tribal groups for their rights
- Provides structural arrangements for organic certification and
- Recognizes private sectors as key stakeholders in designing policies and organic certification.

18. Prime Minister Agriculture Modernization Project (PM-AMP), 2016

Agriculture has been one of the promising sectors for poverty reduction. Since the formulation of the fifth five-year plan (1975-1980) to the tenth five-year plan (2000-2005), the priority for poverty reduction was given to agriculture through increased productivity of the existing crops and diversified production of horticultural crops. Transformation of subsistence farming to more commercialized and diversified was through Agriculture Perspective Plan (1995-2015). However, the growth of the agriculture sector was limited only to 2.9% during the last decade. Therefore, Prime Minister Agriculture Modernization Project (PMAMP) was launched with the objective of specialized production and programs as a national-resourced project in 2016. Then agriculture production programs were initiated based on the specific products area developing zones and super-zones of specific crops, thereby ensuring food and nutritional security of the population, developing value chain of the produce, strengthening the capacity of local organizations, supporting agriculture mechanization, focusing on climate-smart agriculture, ensuring the supply of major inputs, like fertilizer and seeds for increased productivity with marketing networks. All subsidies and incentives for the farmers can be provided channeling through the Provincial Government in all agriculture development activities.

19. Zero Hunger Challenge National Action Plan, 2016–2025

Nepal has undertaken Zero Hunger Challenge (ZHC) to end hunger, food insecurity and malnutrition by 2025 as a vision that invites all stakeholders for collective actions to create a hunger-less society in the country. It has been accepted as a strategy that would consolidate ongoing poverty and hunger eradication efforts of all the national and international development partners working within the country. It intends to make the best use of available resources for both currently targeted and new programs that are identified as necessary for filling the gaps in eradicating hunger in a sustainable manner.

The ZHC initiative emphasizes addressing the issue of food insecurity and malnutrition and improvement for sustainable agriculture and food systems to overcome hunger and malnutrition. Recognizing their interconnected causes for poverty and hunger, they intend to address the underlying factors responsible for poverty, hunger and malnutrition.

20. The Local Government Operation Act (LGOA), 2017

This act recognizes the importance of involving local residents and interested parties in agriculture development. The LGOA authorizes the Gaunpalika/Rural Municipalities and Nagarpalika/Urban Municipalities to conduct the following functions:

- Formulation of policies, laws, standards, and plans related to agriculture and livestock development and their implementation, monitoring, and evaluation.
- Communicating information related to the marketing of agriculture and livestock products, infrastructure building for periodic markets, construction of small irrigation canals, conducting capacity development programs for farmers through training activities.
- Control of natural hazards and epidemics related to agriculture and livestock.
- Conservation of agriculture land and bio-diversity.
- Facilitation of loans for livestock insurance.
- Construction of roads for agriculture.

21. Agri-Business Promotion Policy, 2006

The policy aims to promote market oriented competitive agro products and internal and external markets for sustainable agricultural development and assure food security in the nation. But its main weakness are that commercial production areas, organic production areas, and export oriented production areas not initiated.

22. Agriculture Bio-diversity Policy, 2007

The Agriculture Bio-diversity Policy aims to protect, promote and utilize biodiversity for sustainable agricultural development and assure food security in the country. However, scientific documentation of diversified bio-resources is at a limited level in the country.

23. National Forestry Policy, 2018

The policy aims to build the green economy, creates employment opportunities, supports tourism, increase carbon reservation, increasing biodiversity (wildlife and flora) and water reservoirs through sustainable forest management.

24. National Climate Change Policy, 2019 (2076)

Climate change has been directly experienced in forest and biodiversity, energy, human health, tourism, habitation, infrastructure development as well as in the areas of livelihood, while there has been a huge loss of lives and property due to climate-induced disasters such as flood, landslide, and windstorm and wild fire every year. Against this backdrop, this National Climate Change Policy, 2019 has been introduced with the objective of providing policy guidance to various levels and thematic areas towards developing a resilient society by reducing the risk of climate change impacts. Following are the objectives of the policy:-

(a) To enhance climate change adaptation capacity of persons, families, groups and communities vulnerable to, and at risk of, climate change;

(b) To build resilience of ecosystems that are at risk of adverse impacts of climate change;

(c) To promote green economy by adopting the concept of low carbon emission development;

(d) To mobilize national and international financial resources for climate change mitigation and adaptation in just manner;

(e) To conduct research, make effective technology development and information service delivery related to climate change;

(f) To mainstream or integrate climate change issues into policies, strategies, plans and programs at all levels of State and sectoral areas;

(g) To mainstream gender equality and social inclusion (GESI) into climate change mitigation and adaptation programs"

3.2 Prospects of Agro-ecosystem Services and Policy Gaps

Still, nearly a quarter of the population in the nation is living under conditions of poverty and social deprivation. Poverty alleviation is the biggest long-term development challenge for the government. The growth in agriculture has remained stagnant over decades despite a number of plans and policies at the national level and international supports. In this sense, the plans and policies fail to address problems and issues relating to agriculture to some extent. The agriculture sector in Nepal has been facing a number of problems ranging from policy to implementation level due to many reasons.

- Complete organizational structure in the agriculture sector has not been finalized yet under the federal system, the critical judgments are required to finalize the structure so that needful functions do not get disturbed. The structures should be developed in such a way that highly essential services will be provided by local bodies, development functions by the provincial government and policy and regulatory functions by the central level.
- Agriculture is a diverse sector, it requires specialists services from different disciplines like crop/horticulture/ livestock extension, business plan and market-oriented production schemes; disease and pest management, soil and seed testing; a special unit to link-local bodies to the provincial and central government are essentially required.
- Improved agricultural technologies demand timely availability of improved seed varieties, fertilizers, and technical support including competitive marketing of the farmer's produce, which are not resolved in time. The price for agriculture production and market are complex, which drastically vary from the farmer (producer) to consumer. Farmers' main complaint is the late price-fixing after harvesting period and not paid timely. The crop insurance and security of farmers in terms of their commodity selling is not assured in time.
- Poor or lack of physical access has adverse impacts on the delivery of agricultural inputs on a regular basis, and there is the shortage of agriculture storage centers that is essential in order to boost the commercialization of agriculture.
- Land fragmentation among Nepalese farmers is becoming a problem for the development of commercialization of agriculture, rather agriculture land is reducing due to urbanization.
- Due to climate change and modernization of commercial agriculture solely depending on high chemical inputs, farmers are facing problems of number of insect pests and diseases on crops that are devastating agriculture production and adding costs to farmers.
- The research-oriented agriculture policy and program seem to be supportive of sustainability, which is limited because of meager funding and some results are only in the paper than reaching the needy farmers in various geographic, climatic, soil variability domains of the country.
- To make all realistic, location-specific research, regular funding and technical human resource development are necessary and all these provided by the government are insufficient in the agriculture sector.
- Hence to conclude, the agriculture-friendly economic policy and effective implementation are required for agriculture development.

- National Planning Commission (NPC) is at the top to assess and approve all policies, programs and projects before they go into effect in the country and related stakeholders must have their great role and responsibilities to implement them all effectively.

3.3 Bibliographic databases preparation

3.3.1 Introduction

Food production has to be increased by 70% to feed the projected 9 billion people by 2050. To increase crop production and productivity research, training, and extension are the three major areas of agricultural technology development. Climate change and environment degradation has affected crop production and productivity including ecosystem services. Accordingly, agricultural research is changing over time due to recent development in new varieties, advanced technology practices and climate change. Thus, empowerment of small-scale farmers, particularly in rural areas with adoptive technology is the critical component for this growth. The national scenario of area, production and productivity of crops for 2017/18 are presented in Table 13. Production area is limited and productivity in Nepal is very low as compared to developed countries. Therefore, considering all biodiversity services, increasing production and productivity is vital without disturbing ecosystem services.

Table 13. Area, production and productivity of some crops in Nepal

SN	Crop	Area (ha)	Production (mt)	Productivity (mt/ha)
1.	Cereal	3,428,986	10,012,742	2.920
2.	Oilseed	224,595	245,867	1.095
3.	Citrus	25,964	245,176	9.400
4.	Vegetable	286,864	3,958,230	13.798
5.	Coffee	2650	513	0.193
6.	Pulses	311,382	368,741	1.194
7.	Beekeeping	242,000 (Colony)	3,980	-

Source: CBS (2019)

Agro-ecosystem services

Agroecosystems both provide and rely on ecosystem services to sustain production of food, fiber, and other harvestable goods (Figure 6). Many services have on-farm benefits for farmers, plantation managers, and other people on-site (Table 14).

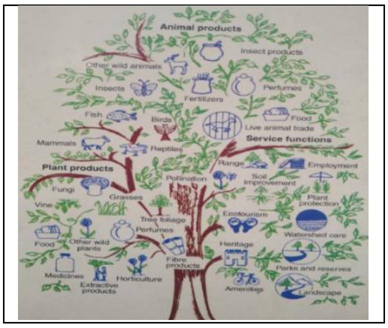


Figure 6. A plant contributing many kinds of benefits to human beings

Source: Kumar (2001)

Table 14. Ecosystem service, descriptions and related on-farm benefits

SN	Ecosystem service	Description	On-farm benefits
1.	Provision of food, feed, fuel and biochemicals	Harvestable goods from agroecosystem	Foods and other goods for on farm consumption or sale
2.	Soil structure and fertility enhancement	Soil structure and processes of nutrient cycling and delivery of nutrient to plants; processing of organic matter and transforming detritus and waste	Support for crop growth and can limit need of chemical fertilizer
3.	Erosion protection	Soil retention limiting soil loss through wind and water erosion	Maintain soil, and the nutrients it contains, to support production
4.	Hydrologic services: Water flow regulation	Buffering and moderation of the hydrologic cycle, including water infiltration into soils and aquifers, moderation of runoff, and plants transpiration	Water in soils, aquifers, and surface bodies available to support plant growth
5.	Hydrologic services: Water purification	Filtration and absorption of particles and contaminants by soil and living organisms in the water and soil	Clean water available for human consumption, irrigation, and other on-farm uses
6.	Pollination	Transfer of pollen grains to fertilize flowers	Necessary for seed set and fruit production in flowering plants and crops
7.	Pest control	Control of animal and insect pests by their natural enemies – predators, parasites, and pathogens	Minimize crop damage and limit competition with crops
8.	Weed control	Botanical component of pest control; suppressing weeds, fungi, and other potential competitors through physical and chemical properties of cover crops, intercrops, and other planted elements	Minimize weed competition with crops
9.	Carbon sequestration	Atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass and soils	Few demonstrable on-farm benefits
10.	Genetic resources	Pool of genetic diversity needed to support both natural and artificial selection	Distinct genotypes (cultivars) allow fruit set in orchards and hybrid seed production; trait diversity (from landraces and wild relatives) supports disease resistance, new hybrids, and climate adaptations
11.	Cultural and esthetic services	Maintaining landscapes that support: esthetics and inspiration; spiritual and religious values; sense of place; cultural heritage; recreation and ecotourism	Esthetics and inspiration; spiritual and religious values; sense of place; cultural heritage; recreation and ecotourism

Source: Garbach et al. (2014)

3.3.2 Soil organisms and plant elements

A fertile soil harbors diverse arrays of abundant organisms (Table 15) as indicators and also a plant growing in fertile soil is a reservoir of nutrients, which is essential for a plant to grow from a seed and complete its life cycle (Table 16).

Table 15. Number of organisms in average farm soil

SN	Organisms	Quantity
1.	All arthropods (including insects)	725 million/ha
2.	Insects	23 million/ha
3.	Bacteria	2.5 billion /gm
4.	Algae	50,000 /gm
5.	Earthworm	6 million/ha

Source: USDA (1985)

Table 16. Essential elements required for plant growth, production and productivity

SN	Element	Form primarily absorbed by plants	Mass (%) in dry tissue	Major functions
	Macronutrients			
1	Carbon	CO_2	45	Major component of plant's organic compounds
2	Oxygen	CO_2	45	Major component of plant's organic compounds
3	Hydrogen	H_2O	6	Major component of plant's organic compounds
4	Nitrogen	NO_3^-, NH_4^+	1.5	Component of nucleic acids, proteins, hormones, chlorophyll, coenzyme
5	Potassium	K^+	1	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
6	Calcium	Ca^{2+}	0.5	Important informations and stability of cell walls and in maintenance of membrane structure and permeability, activates some enzyme; regulates many responses of cells to stimuli
7	Magnesium	Mg^{2+}	0.2	Component of chlorophyll; cofactor and activator of many enzymes
8	Phosphorus	$H_2PO_4^+$, HPO_4^{2-}	0.2	Component of nucleic acids, phospholipids, ATP, several coenzymes
9	Sulfur	SO_4^{2-}	0.1	Component of proteins, coenzymes
	Micronutrients			
1	Chlorine	Cl^-	0.01	Requiring for water splitting step of photosynthesis; functions in water balance
2	Iron	Fe^{3+}, Fe^{2+}	0.01	Components of cytochromes; cofactor of some enzymes, needed for photosynthesis
3	Manganese	MN^{2+}	0.005	Active in formation of amino acids; activates some enzymes, required for water splitting step of photosynthesis
4	Boron	$H_2BO_3^-$	0.002	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall formation
5	Zinc	ZN^{2+}	0.002	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
6	Copper	Cu^+, Cu^{2+}	0.001	Compound of many redox and lignin-biosynthetic enzymes
7	Nickle	Ni^{2+}	0.001	Cofactor of enzyme functioning in nitrogen metabolism
8	Molybdenum	MoO_4^{2-}	0.0001	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

Source: Huang *et al.* (2008)

Basically, soil health is crucial for increasing productivity as it harbors enormous soil inhibiting micro- and macro-organisms. The ecosystem services provided by soil organisms include: decomposition and nutrient cycling, carbon sequestration, maintenance of plant diversity and soil fertility.

3.3.3 Beneficial insects

Most insects are beneficial in natural ecosystems. As farmers grow crops, certain insects feed on these plants and are thus deemed pests. There are several insects that prey on or parasitize these pest insects (Table 17). Predatory insects are general feeders (feeding many species) or specific feeders (feeding only one or a few species). Parasitoids generally have one offspring develop in a single host insect. In addition, many insects pollinate crops.

Table 17. Some beneficial insects in an agro-ecosystem

SN	Insect	Picture	Use
1.	Lady beetle		Ladybeetles often feed on mites, thrips, scales and aphids.
2.	Lace wing		Lace wings feed on aphids.
3.	Preying mantid		Preying mantids are general predators that catch and feed on moving insects.
4.	Assassin bug		They are general feeders with sucking mouthparts.
5.	Ground beetle		They are fast moving insects and prey on other insects.
6.	Syrphid fly		Adult flies are beneficial for pollination, while the larvae feed on aphids.
7.	Tachnid fly		They feed on other insects.
8.	Braconids		They parasitize on other insects.
9.	Trichogramma		The minute wasps attack insect eggs.
10.	Honeybee		Bees are the best pollinators of plants.
11.	Bumble bee		They are important pollinators of plants.
12.	Wasps		Wasps make mud nests and prey on other insects.

Source: Barbosa (1998).

3.3.4 Pesticidal plants

Commercial products of neem are available in the market and farmers are using them in vegetables and other field crops. In scattered areas, farmers have been using various botanicals in crude form on various crops in the field and in storage for controlling a variety of pests (Table 18).

Table 18. Pesticidal value of Nepal's indegenous plants

SN	Scientific name of plant	Nepali name	Part and mode of preparation	Action and properties
1.	*Acorus calamus* L.	Bojho	Bulb	Insecticide, insect repellent & contact poison
2.	*Agave Americana* L.	Ketuki	Plant sap	Insect repellent and fish poison
3.	*Allium sativum* L.	Lashun	Bulb	Insect repellent

4.	*Annona squamosa* L.	Sarifa	Leaves, immature fruits & seeds.	Insecticide and parasiticide due to glycerol of hydroxilated acid
5.	*Artemisia vulgaris* L.	Tite pati	Green or dried foliage	Repellent and fumigant against insects due to Santonin, an alkaloid
6.	*Boenin ghausenin albiflora*	Ankuri	Plant & leaf extract	Insect repellent specially to flies
7.	*Canna indica* L.	Sarbada	Extract of flower	Insecticide
8.	*Cinnamomum camphora* Nees	Kapoor	Wood solid crystal	Insect repellent used in preparation of insecticides
9.	*Crotalaria juncea* L.	Chhinchhine	Flower extracts	Effective against many insects
10.	*Chenopodium botrysis* L.	Bethe	Whole plant	Insect repellent
11.	*Derris elliptica* Bench.	Deri	Lateral line root & powdered root	Rotenone extracted from root is active ingredient of many insecticides. Root powder used as insect powder for pets
12.	*Digitalis purpurea* L.	--	Leaves and seeds	Pesticide
13.	*Feenum graeccum*	Methi	Seed	Source of insect repellent and insecticide, due to an alkaloid Trigenelline
14.	*Gynandropsis*	Marcha	Seed oil	Vermicide
15.	*Hedera helix* L.	Kathe lahare	Whole plant	Resistance to some insects
16.	*Heynea trijuga* Rexb.	Ankha taruwa	Foliage	Insect repellent
17.	*Hedychium spp.*	Kewara	Rhizome	Effective against harmful bacteria & fungi due to essential oil
18.	*Kalanchoe pinnata* pers.	Ajambari	Plant juice	Insect repellent
19.	*K. spathulata* DC	Hatti kane	Plant juice	Insect repellent
20.	*Litsea cubeba* Pers	Siltimmur	Leaves & fruits	Insect repellent, wormicide
21.	*Lannea grandis* Engle	Hallongre	Wood	Resistant to termites due to jingan gum
22.	*Mangifera indica* L.	Aap	Powdered plant	Fumigant against mosquito
23	*Mesua ferrea* L.	Nageswar	Wood	Resistant to some types of termites
24.	*Melia azedarach* L.	Bakaino	Foliage, fruit, wood & seed oil	Insecticide & insect repellent. Insecticide preparation due to Nimbidin
25.	*Nicandra phaseoloides* Gaertn	Madisetil	Fresh foliage	Insecticide
26.	*Nicotiana rustica*	Beleyati surti	Leaf	Insecticide and wormicide due to an alkaline Nicotine
27.	*Nicotiana tabacum*	Lampate surti	Leaf	Insecticide and wormicide due to an alkaline Nicotine
28.	*Nerium odorum* Ait	Pahelo karabir	Root, stem, leaf, flower, fruit extract	Contact and stomach poison to rodents, due to Nerin, an alkaloid
29.	*Sapindus mukorossi* Gaertn	Rittha	Fruit	Insecticide and fish poison
30.	*Sesamum indicum* L.	Sesame	Till	Major ingredient of insecticidal preparation
31.	*Tagetes minuta* L.	Sanosayapatri	Foliage	Insect repellent
32.	*Zanthoxylum armatum* DC	Timur	Fruit decoction foliage	Wormicide insect repellent & fish poison, due to Neehercullin an insecticidal component
33.	*Zingiber officinale* Rose	Aduwa	Ingression of rhizome extract	Body immunity against mosquitoes. Insecticide due to essential oil.

Source: Dahal, et al. (1995)

3.4 Production practices

Apple production practices

High hill region is well known for commercial cultivation of apple. It is cultivated in Jumla, Mugu, Kalikot Mustang, and part of Rasuawa, Sindhupalchok, Dolakha, Solukhumbu, Rukum, Rolpa. *Soil fertility*: In the apple growers' fields, soil tests for pH, organic matter, NPK and maintaining soil fertility is essential. *Nursery and orchard management:* Nursery soil and site should be free from insect pests and disease, and planting materials purchased from reliable source/registered nursery. Similarly, orchard management includes intercropping, mulching, fertilization and pest management practices in eco-friendly way, such as use of FYM with *Trichoderma* 1.5 kg in 50 kgs of FYM and apply fortified FYM compost to each matured trees helps minimize root rot disease of apple. For insect pest management, spray of Servo oil @10 ml /l of water or Neem based pesticide@3-5 ml/l of water and use of Bt. @ 2gm/l of water at 7 days interval is suggested. During the flowering period honeybees are important for assured pollination of crops (FAO, 2014).

Citrus production practices

Citrus is cultivated in mid hill region of Nepal. *Soil fertility*: like in apple, citrus growers' fields needs soil tests for pH, organic matter, NPK and maintaining soil fertility. *Nursery and orchard management:* Nursery soil and site should be free from insect pests and disease, and planting materials purchased from reliable source/registered nursery. Fertilizer application is adjusted according to the soil test results. Growing legume crops as intercropping helps improve soil fertility, as well as trap crops for insect pests and cover crop for moisture retention. Drenching / pasting/ foliar spray with 1% Bordeaux mixture/paste/spray suppress diseases. Citrus psylla transmits citrus greening disease, so timely treatment with Neemoil 4ml/l, and servo oil 2ml/l are useful. Bioagents like, predators like ladybeetles, syrphid fly help suppress pest problems. For fruit fly management food baits and lures are effective when practiced in area wide basis. During the flowering period honeybees are important for assured pollination of crops. Spraying microbial consortium (Bio-fit) @ 1g /l or spraying *Ampelomyces quisqualis* (Powdery Care) @ 0.6g /l water protects cucurbits from mildew diseases (FAO, 2014).

Vegetable production practices

Different kinds of vegetables are cultivated by farmers for home consumption and sale. *Soil fertility*: like above growers' fields need soil tests for pH, organic matter, NPK and maintaining soil fertility. *Nursery and farm management:* Nursery soil and site and planting materials should be free from insect pests and diseases. Similarly, controlling aphids or whitefly through predators, parasites is useful to suppress vector transmitted diseases. For fruit fly control, pheromone traps should be placed about 5 per 5000m^2 (FAO, 2014).

3.5 Bibliography database

This bibliography reviews and enlists the relevant literature in project mandated crops like apple, citrus, maize, rapeseed, and cucurbits in respect to eco-friendly cultivation practices of these crops and without disturbing ecosystem services.

1. Abel, C.A., Wilson, R.L., Luhmann, R.L. 2003. Pollinating efficacy of *Osmia cornifrons* and *Osmia lignaria* subsp. l*ignaria* (Hymenoptera: Megachilidae) on three Brassicaceae species grown under field cages. J.Kans.Entomol.Soc. 38:545-552.
2. Adara Pardo and Paulo A.V. Borges. 2020. Worldwide importance of insect pollination in apple orchards: A review, Agriculture, Ecosystems & Environment.106839, 293. https://doi.org/10.1016/j.agee. 2020.106839. Apple *(Malus domestica*) is one of the most important fruit crops globally. Apple trees depend greatly on insect pollination to achieve high yields and obtain fruits of acceptable marketable quality. Since insects, such as bees and hoverflies, are most important pollinators in apple orchards, a comprehensive understanding of their occurrence and activity is vital to ensure pollination services in this agroecosystem. Here, we review and synthesize the published research on the contribution of insects to apple pollination. In our review, we focused on the following five questions: i) Are there gaps in data availability across geographical regions and research topics? ii) What is the importance of insect pollination at determining yield and fruit quality in apple orchards? iii) What is the relative contribution of wild insects to apple pollination compared to honeybees? iv) What is the influence of landscape context (matrix) on regulating apple pollination? and v) How does agricultural management affect apple pollination?. Results showed that the information is limited for certain large apple producing countries, like China or Brazil. This finding stresses the need for further research in less studied regions. There were also gaps across research topics, highlighting the need for more experimental and empirical studies, particularly on the effect of local management practices on apple pollination. Substantial evidence from qualitative analyze. s supports the fact that insect pollination is essential for ensuring both yields and fruit quality in apple orchards across different regions. Besides, a significant proportion of studies showed that wild pollinators are abundant in apple orchards and they are frequently more effective pollinators than honeybees. Current available findings suggest a critical role of diverse semi-natural habitats surrounding apple orchards to sustain healthy pollinator communities, while the effect of local management was less consistent.
3. Adegas, J.E.B., and R.H. Nogueira Couto 1992. Entomophilous pollination in rape (*Brassica napus* L. var. *oleifera*) in Brazil. Apidologie 23:203-209.
4. Adhikari, S. 2004. Bumblebees and their relationship with flower morphology of *Pedicularis* species in Nepal. Proceedings of 4th National Conference on Science and Technology edited in 2006, NAST, Kathmandu, Nepal.

5. Adhikari, S. 2005. *Plant*-Pollinator Interaction of the Himalayan Lousewort's with Reference to *Pedicularis dendrothauma. In:* R. R. Mill and D. J. Allard (eds.) Paper presented on Asia Section 1st Regional Conference of Society for Conservation Biology, 17-20 November 2005. Organized by the Society for Conservation Biology Asia Section, Kathmandu, Nepal.

6. Adhikari, S. and N.B. Ranabhat. 2011. Bee flora in mid hills of Central Nepal. Journal of Plant Science, Central Department of Botany, Trivuvan University, Kathmandu, Nepal. Beekeeping is one of the promising ventures for economically poor families in Nepal. Knowledge about the bee flora of a certain area is very crucial for the farmers. A study was conducted in mid hills of Central Nepal during 2003-04 and 2008-09 to monitor the common plant species visited by bees with their visiting time and seasons. The flowering period of those plant species were also observed. Observations were made on the bees' activities on flowers of different plant species. Relevant information was also collected through informal key informant interviews. The plant species visited by the bees and the bee species (mainly *Apis cerana* with some *Apis melifera*) themselves were collected, preserved and identified. Plants were categorized as major, medium and minor sources of pollen and/or nectar. The pollen and nectar statuses in different plants were also determined. A total of 158 plant species were identified as main bee flora in the study area. Among them, 19 species were horticultural plants, 42 species were crop plants, 15 species were ornamental plants and 82 species were wild plants. In total, 38 species were recognized as major, 35 as medium and 30 as minor sources for both nectar and pollen. Months from March to May and August to October were the honey flow periods. Species of *Brassica, Citrus, Pyrus, Berberis, Rubus, Callistemon*, *Bombox* and *Artemisia* were some of the important plants which bloomed during those months. Winter (mid November to January) and rainy (June and July) seasons were identified as the dearth periods for bees to collect honey. Some of the plants that bloom during winter were *Pisum sativum, Ipomoea batata* and *Eupatorium* sp. Similarly, *Lagerstroemia* sp., *Impatiens balsamina*, *Sesamum indicum*, *Zea mays* and many cucurbits bloomed during rainy season. Study has shown that mid-hills of Central Nepal is rich in bee flora and has great potential for beekeeping as many plants bloomed even in dearth periods.

7. Adlerz, W. C. 1966. Honey bee visit numbers and watermelon pollination. *J. Econ. Ent.* 59: 28-30.

8. Adriano Sofo, Alba Nicoletta Mininni, and Patrizia Ricciuti. 2020. Soil Macro-fauna: A key Factor for Increasing Soil Fertility and Promoting Sustainable Soil Use in Fruit Orchard Agro-systems. Agronomy 10:4, pages 456. Soils and crops in orchard agro-systems are particularly vulnerable to climate change and environmental stresses. In many orchard soils, soil biodiversity and the ecosystem service it provides are under threat from a range of natural and manmade drivers. In this scenario, sustainable soil use aimed at increasing soil organic matter (SOM) and SOM-related benefits, in terms of soil quality and fertility, plays a crucial role. The role of soil macro-faunal

organisms as colonizers, comminutors and engineers within soils, together with their interactions with microorganisms, can contribute to the long-term sustainability of orchard soils. Indeed, the continuous physical and chemical action of soil fauna significantly affects SOM levels. This review paper is focused on the most advanced and updated research on this argument. The analysis of the literature highlighted that a significant part of soil quality and fertility in sustainably-managed fruit orchard agro-systems is due to the action of soil macro-fauna, together with its interaction with decomposing microorganisms. From the general analysis of the data obtained, it emerged that the role of soil macro-fauna in orchards agro-systems should be seriously taken into account in land management strategies, focusing not exclusively on fruit yield and quality, but also on soil fertility restoration.

9. Afrin, S., A. Latif, N.M.A. Banu, M.M.M. Kabir, S.S. Haque, M.M. Emam Ahmed, N.N. Tonu, and M.P. Ali. 2017. Intercropping Empower Reduces Insect Pests and Increases Biodiversity in Agro-Ecosystem. Agricultural Sciences, 8, 1120-1134. https://doi.org/10.4236/as.2017.810082. Currently insect pest management solely depends on chemical pesticide that continuously affects on environment, biodiversity, animal as well as human health. Outbreak of secondary insect pest is also the cost of pesticide use in field leading crop more vulnerable to more pests. These negative impacts of pesticides have provoked growing interest in the adoption of multi-function agricultural biodiversity that promote pest management, creating interesting challenge for traditional approaches to regulatory compliance. To address multi-function agricultural practice, we tested several intercropping systems with mustard and their effect on pest management. Our results revealed that intercropping systems mustard with onion, garlic, radhuni and coriander significantly reduced pest population over sole crop. However, intercropping mustard with wheat and gram increased pest population in mustard field. This result indicated that all crops are not suitable for intercropping system. Among the tested intercropping systems, mustard with onion and coriander significantly reduced branch and flower infestation and increased pod formation per plant. These four intercropping systems did not significantly affect on honeybee pollinator which are crucial for mustard crop yield. A significant linear relationship was also found between honeybee population and pod formation. Our results indicate that suitable intercropping system can be a potential multi-functional agricultural practice for pest management in mustard crop.

10. Ahmad, F., U. Partap, S. R. Joshi, and M. B. Gurung. 2002. Why the Hindu Kush Himalayan (HKH) Fragile? *In:* M. Matsuka, L. R. Verma, S. Wongsiri, K. K. Shrestha and U. Pratap. (eds) Asian Bees and Beekeeping Progress of Research and Development. Oxford and IBH Pub. Co. Pvt. Ltd, New Delhi, India. pp. 262-265. (Abstract: This chapter explains the role of honeybees, with special reference to Asian species, in pollination and so enhancing crop productivity and conserving biodiversity. The problems in natural pollination and agricultural systems, declines in the populations and diversity of natural pollinators and their causes are discussed. The chapter

describes the advantages of Asian hive bees, *Apis cerana*, over European honeybees, *Apis mellifera*, in pollinating various crops, especially in mountain areas. The general principles of managing honeybee colonies for pollination are defined. Finally, the challenges and solutions to mainstream honeybees and beekeeping in agricultural and horticultural development policies and practices in Asia are described.

11. Aidoo, O., R. Kyerematen, C. Mensah, and K. A. Nuamah. 2016. Abundance and Diversity of Insects Associated with Citrus Orchards in Two Different Agro-ecological Zones of Ghana. Journal of Experimental Agriculture International, 13(2), 1-18. https://doi.org/10.9734/AJEA/2016/26238. We investigated the abundance and diversity of entomo-fauna associated with citrus orchards in two different agro-ecological zones of Ghana. Malaise traps, flight interception traps, pitfall traps, chemical ‘‘knock down’’ and visual observation were used for data collection. We recorded a total of 20, 285 individual insects belonging to 387 species from 107 families and 13 orders. Although, several species of insects were common to both agro-ecological zones, some were more specific to an orchard of a particular zone. Diversity indices such as Shannon-Wiener index, Pielou’s evenness and Margalef index were higher in the Coastal Savannah zone than the Semi-Deciduous Rainforest zone during both the wet and the dry seasons. *Oecophylla longinoda* Latreille was the most dominant insect species in each agro-ecological zone, however, they were more abundant in the semi-deciduous rainforest than the Coastal Savannah zone. Our study shows that only 9% of all the 387 insects collected were pests of citrus. This indicates that citrus orchards are potential habitats for insect biodiversity conservation. We therefore recommend that management tactics which have less or no negative effects on natural enemies, pollinators among others but can effectively suppress insect pest populations (such as the use of biological control agents, restriction of herbicides and pesticides) should be adopted. Our study has also provided the first comprehensive inventory of insect species associated with citrus agroecosystems serving as a baseline data for further studies to encourage adoption of economically sound integrated pest management approach for citrus production in Ghana.

12. Alam, M.Z., Quadir, M.A., Ali, M. 1987. Pollinating behavior of honeybee, *Apis indica* F. and its influence on seed production of cauliflower. Bangladesh Horticulture 15:25-30.

13. Alex, A.H. 1957. Honeybees aid pollination of cucumbers and cantaloupes. Gleanings in Bee Culture 85:398-400.

14. Aliev, T.A. 1971. Use of honeybees for mustard pollination. 23rd International Congress on Apiculture.

15. Allen-Wardell G, Bernhardt P, Bitner R, Burquez A, Buchmann S, Cane J. *et al*. 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conserv. Biol. 12: 1–8. Following reports of dramatic declines in managed and

feral honey bees from nearly every region of North America, scientists and resource managers from the U.S., Mexico, and Canada came together to review the quality of the evidence that honey bees as well as other pollinators are in long-term decline and to consider the potential consequences of these losses on the conservation of biodiversity and the stability of the yield of food crops. These experts in pollination ecology confirmed that the last 5 years of losses of honeybee colonies in North America leave us with fewer managed pollinators than at any time in the last 50 years and that the management and protection of wild pollinators is an issue of paramount importance to our food supply system. Although there are conclusive data that indicate 1200 wild vertebrate pollinators may be at risk, data on the status of most invertebrate species that act as pollination agents is lacking. The recommendations from a working group of over 20 field scientists, presented here, have been endorsed by 14 conservation and sustainable agriculture organizations, research institutes, and professional societies, including the Society for Conservation Biology. Among the most critical priorities for future research and conservation of pollinator species are (1) increased attention to invertebrate systematics, monitoring, and reintroduction as part of critical habitat management and restoration plans; (2) multi-year assessments of the lethal and sublethal effects of pesticides, herbicides, and habitat fragmentation on wild pollinator populations in and near croplands; (3) inclusion of the monitoring of seed and fruit set and floral visitation rates in endangered plant management and recovery plans; (4) inclusion of habitat needs for critically-important pollinators in the critical habitat designations for endangered plans; (5) identification and protection of floral reserves near roost sites along the 'nectar corridors' of threatened migratory pollinators; and (6) investment in the restoration and management of a diversity of pollinators and their habitats adjacent to croplands in order to stabilize or improve crop yields. The work group encourages increased education and training to ensure that both the lay public and resource managers understand that pollination is one of the most important ecological services provided to agriculture through the responsible management and protection of wildland habitats and their populations of pollen-vectoring animals and nectar-producing plants.

16. Altiere, M. A. 1999. The ecological role of biodiversity in agroecosystems. Agriculture Ecosystems & Environment, 74, 19–31. https://doi.org/10.1016/S0167-8809(99)00028-6. Increasingly research suggests that the level of internal regulation of function in agroecosystems is largely dependent on the level of plant and animal biodiversity present. In agroecosystems, biodiversity performs a variety of ecological services beyond the production of food, including recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals. In this paper the role of biodiversity in securing crop protection and soil fertility is explored in detail. It is argued that because biodiversity mediated renewal processes and ecological services are largely biological,

their persistence depends upon the maintenance of biological integrity and diversity in agroecosystems. Various options of agroecosystem management and design that enhance functional biodiversity in crop fields are described.

17. Alva, A.K., D.J. Mattos and S. Paramasivam *et al*. 2006. Potassium management for optimizing citrus production and quality. Int J Fruit Sci 6:3–43. doi: 10.1300/J492v06n01_02. Potassium (K) is highly mobile in plants at all levels, that is, from individual cell to xylem and phloem transport. This cation plays a major role in (1) enzyme activation; (2) protein synthesis; (3) stomatal function; (4) stabilization of internal pH; (5) photosynthesis; (6) turgorrelated processes; and (7) transport of metabolites. Citrus trees generally do not show visible deficiency symptoms across a wide range of K status in the leaves, except when the leaf concentrations drop below 3-4 mg kg21. However, fruit quality is quite sensitive to varying levels of K availability. High levels of K cause large fruit size with thick and coarse peel. In contrast, K deficiency produces smaller fruits with thin peel. With regard to juice properties, K nutrition has a significant role in juice acidity; that is, high juice acidity with high K availability, while low K availability causes decrease in juice acidity. High K availability in the soil can reduce the uptake of other cations, primarily magnesium, calcium, and ammonium N. In this paper, the available information on the effects of varying availability of K on the fruit yield, postharvest quality of fruit, as well as juice quality is summarized. The current recommendations on the application of soil and leaf analysis for evaluation of the K nutritional status and guidelines for K fertilization are also discussed.

18. Andersen L., B.F. Kühn, M. Bertelsen, M .Bruus, S.E. Larsen, and M. Strandberg. 2013. Alternatives to herbicides in an apple orchard, effects on yield, earthworms and plant diversity. Agric. Ecosys. Environ. 172:1–5. doi:10.1016/j.agee.2013. 04.004. https://doi.org/10.1016/j.agee.2013.04.004. In a newly established apple orchard eight alternative methods to weed control in the tree row were compared to a herbicide treatment with respect to effects on tree growth, first-quality fruit yield, earthworms and flora. All treatments were tested at two irrigation schedules, with similar amount of water at a daily or weekly basis. In general, daily irrigation reduced first-quality fruit yield compared to weekly irrigation. Mulching with black polypropylene (MyPex®) and rape straw had a positive effect on first-quality yield and shoot growth, only black polypropylene, compared to herbicide treatment, whereas mulching with paper wool reduced first-quality fruit yield compared to herbicide treatment. Cover crop as tagetes and weed harrowing had similar yield as herbicide treatment, whereas cover crops as grass and hop medick and weed cutting reduced first-quality yield compared to herbicide treatment. Earthworms thrived under rape straw contrary to under black polypropylene and plots with weed harrowing. Treatments had significant effects on species numbers of plants both years, and total vegetation cover generally increased in the second year. Rape straw supported a high production of apples and a large stock of earthworms; however, its support of wild flora is poor, when it is taken into

account that a large proportion of the flora in the rape straw was rape established from seeds left with the straw.

19. Andreev, R., R. Olszak, and H. Kutinkova. 2006. Harmful and beneficial entomo-fauna in apple orchards grown under different management systems, Bull. IOBC/wprs 29, 13–19. During the period 1996-2004, the harmful and beneficial insects were observed in apple orchards of the Agricultural University Plovdiv, Bulgaria, grown under different management systems: biological, integrated and conventional (chemical). A total of 43 pests, belonging to 27 families and 5 orders were recorded in the orchard under biological pest management (BPM). In the orchards under IPM and chemical pest management (CPM) 35 and 26 species were found, respectively. The codling moth, Cydia pomonella, is the main pest of all apple orchards in Bulgaria. Other pests with a high population density in the BPM-orchard were the apple sawfly *Hoplocampa testudinea*, the pear lace bug *Stephanitis pyri*, tortricid-moths, the apple clearwing *Synanthedon myopaeformis*, the leopard moth *Zeuzera pyrina* and the weevils: Phyllobius oblongus, *Rhynchites bacchus* and *R. aequatus*. The populations of aphids, leafminers, *Epicometis hirta* and leaf-eating caterpillars increased occasionally. The populations of harmful insects in the IPM-orchard (aphids, leafminers, leopard moth and apple clearwing) increased occasionally. A high population density of harmful insects in the CPM-orchard (leafminers, aphids, *Epicometis hirta*, leopard moth and apple clearwing) was periodically observed. Beneficial insects were very abundant in the BPM-orchard. A total of 30 predators were found, belonging to 4 orders and 7 families. The ladybirds presented the highest population density and were significant as natural regulators of the small pests. Parasitoids from 7 families of Hymenoptera were important natural regulators of aphids, scale insects, leafminers, and tortricids. The population density of beneficial insects was lower in the IPM-orchard, but their importance as natural regulators of pests was still significant. In the CPM-orchard they were found occasionally.

20. Balzan, M., G. Bocci, and A. Moonen. 2014. Augmenting flower trait diversity in wildflower strips to optimise the conservation of arthropod functional groups for multiple agroecosystem services. J Insect Conserv 18:713–728. doi:10.1007/s10841-014-9680-2. Sown wildflower strips are increasingly being established in Europe for enhancing arthropod conservation and the provision of ecosystem services, including biotic pollination and natural pest control. Here we use floral traits to identify different plant functional effect groups. Floral resources were provided in four experimental levels characterised by a cumulatively increasing flower trait diversity and vegetation stand complexity. The first level consisted of a bare control strip, whilst in each subsequent level three wildflower species with different functional traits were added (Level 0: control; Level 1: three Apiaceae species; Level 2: three Apiaceae and three Fabaceae species; Level 3: three Apiaceae, three Fabaceae species, and *Centaurea* jacea (Asteraceae), Fagopyrum esculentum (Polygonaceae), Sinapis alba (Brassicaceae)). Plots with sown wildflower strip

mixtures were located adjacent to experimental plots of organically-managed tomato crop, which is attacked by multiple pests and partially relies on bees for fruit production, and hence dependent on the provision of pollination and pest control services. Results obtained here show that the inclusion of functionally diverse wildflower species was associated with an augmented availability of floral resources across time, and this increased the abundance of bees and anthocorids throughout the crop season. Several natural enemy groups, such as parasitoids, coccinelids and ground-dwelling predators, were not significantly enhanced by the inclusion of additional flower traits within the strips but the presence of flower resources was important to enhance their conservation in an arable cropping system.

21. Balvanera, P., A. B. Pfisterer, N. Buchmann *et al*. 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters* 9.10: 1146- 1156. The authors analyzed 446 studies of biodiversity effects on ecosystem functioning. Their analyses showed that biodiversity effects were stronger at the community level than the ecosystem level, and that productivity-related effects decline with increasing number of trophic links between the manipulated and the measured elements.

22. Barbosa, P. (ed.) 1998. Conservation Biological Control. Academic Press, London, UK. 396 p.

23. Barzman, M., P. Bàrberi, A. Birch, P. Boonekamp, S. Dachbrodt-Saaydeh, B. Graf, B. Hommel, J. Jensen, J. Kiss, P. Kudsk, J. Lamichhane, A. Messéan, A. Moonen, A. Ratnadass, P. Ricci, J. Sarah, and M. Sattin . 2015. Eight principles of integrated pest management. Agron Sustain Dev 35:1199–1215. doi:10.1007/s13593-015-0327-9. The use of pesticides made it possible to increase yields, simplify cropping systems, and forego more complicated crop protection strategies. Over-reliance on chemical control, however, is associated with contamination of ecosystems and undesirable health effects. The future of crop production is now also threatened by emergence of pest resistance and declining availability of active substances. There is therefore a need to design cropping systems less dependent on synthetic pesticides. Consequently, the European Union requires the application of eight principles (P) of Integrated Pest Management that fit within sustainable farm management. Here, we propose to farmers, advisors, and researchers a dynamic and flexible approach that accounts for the diversity of farming situations and the complexities of agroecosystems and that can improve the resilience of cropping systems and our capacity to adapt crop protection to local realities. For each principle (P), we suggest that (P1) the design of inherently robust cropping systems using a combination of agronomic levers is key to prevention. (P2) Local availability of monitoring, warning, and forecasting systems is a reality to contend with. (P3) The decision-making process can integrate cropping system factors to develop longer-term strategies. (P4) The combination of non-chemical methods that may be individually less efficient than pesticides can generate valuable synergies. (P5) Development of new biological agents and products and the use of existing databases offer options for the selection of products minimizing

impact on health, the environment, and biological regulation of pests. (P6) Reduced pesticide use can be effectively combined with other tactics. (P7) Addressing the root causes of pesticide resistance is the best way to find sustainable crop protection solutions. And (P8) integration of multi-season effects and trade-offs in evaluation criteria will help develop sustainable solutions.

24. Beers, E.H., D.M. Suckling, R.J. Prokopy, and J. Avilla .2003. Ecology and management of apple arthropod pests. In: Ferree D, Warrington IJ (eds) Apples: botany, production and uses. CAB Intern. CABI, Wallingford, pp 489–519.

25. Belmonte, S.A., L. Celi, R.J. and Stahel, *et al*. 2018. Effect of Long-Term Soil Management on the Mutual Interaction Among Soil Organic Matter, Microbial Activity and Aggregate Stability in a Vineyard. Pedosphere 28:288–298. https://doi.org/10.1016/S1002-0160(18)60015-3. Vineyard management practices to enhance soil conservation principally focus on increasing carbon (C) input, whereas mitigating impacts of disturbance through reduced tillage has been rarely considered. Furthermore, information is lacking on the effects of soil management practices adopted in the under-vine zone on soil conservation. In this work, we evaluated the long-term effects (22 years) of alley with a sown cover crop and no-tillage (S + NT), alley with a sown cover crop and tillage (S + T), and under-vine zone with no vegetation and tillage (UV) on soil organic matter (SOM), microbial activity, aggregate stability, and their mutual interactions in a California vineyard in USA. Vegetation biomass, microbial biomass and activity, organic C and nitrogen (N) pools, and SOM size fractionation and aggregate stability were analysed. Soil characteristics only partially reflected the differences in vegetation biomass input. Organic C and N pools and microbial biomass/activity in S + NT were higher than those in S + T, while the values in UV were intermediate between the other two treatments. Furthermore, S + NT also exhibited higher particulate organic matter C in soil. No differences were found in POM C between S + T and UV, but the POM fraction in S + T was characterized by fresher material. Aggregate stability was decreased in the order: S + NT > UV > S + T. Tillage, even if shallow and performed infrequently, had a negative effect on organic C and N pools and aggregate stability. Consequently, the combination of a sown cover crop and reduced tillage still limited SOM accumulation and reduced aggregate stability in the surface soil layer of vineyards, suggesting relatively lower resistance of soils to erosion compared to no-till systems.

26. Bender, S.F., and M.G.A. van der Heijden. 2015. Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses. J. Appl. Ecol. 52:228–239. https://doi.org/10.1111/1365-2664.12351. Efficient resource use is a key factor for sustainable production and a necessity for meeting future global food demands. However, the factors that control resource use efficiency in agro-ecosystems are only partly understood. We investigated the influence of soil biota on nutrient leaching, nutrient-use efficiency and plant performance in outdoor, open-top lysimeters comprising a volume of 230 L. The lysimeters were

filled with sterilized soil in two horizons and inoculated with a reduced soil-life inoculum (soil biota ≤11 µm, microbially dominated) and an enriched soil-life inoculum [soil organisms ≤2 mm, also containing arbuscular mycorrhizal fungi (AMF)]. A crop rotation was planted, and nutrient leaching losses, plant biomass and nutrient contents were assessed over a period of almost 2 years. In the first year of the experiment, enriched soil life increased crop yield (+22%), N uptake (+29%) and P uptake (+110%) of maize and strongly reduced leaching losses of N (−51%, corresponding to a reduction of 76 kg N ha−1). In the second year, wheat biomass (+17%) and P contents (+80%) were significantly increased by enriched soil life, but the differences were lower than in the first year. Enriched soil life also increased P mobilization from soil (+112%) and significantly reduced relative P leaching losses (−25%), defined as g P leached per kg P plant uptake, as well as relative N leaching losses (−36%), defined as kg N leached per kg N plant uptake, demonstrating that nutrient-use efficiency was increased in the enriched soil-life treatment. Soil biota are a key factor determining resource efficiency in agriculture. The results suggest that applying farming practices, which favour a rich and abundant soil life (e.g. reduced tillage, organic farming, crop rotation), can reduce environmental impacts, enhance crop yield and result in a more sustainable agricultural system. However, this needs to be confirmed in field situations. Enhanced nutrient-use efficiency obtained through farming practices which exert positive effects on soil biota could result in reduced amounts of fertilisers needed for agricultural production and reduced nutrient losses to the environment, providing benefits of such practices beyond positive effects on biodiversity.

27. Bengtsson, J. 1998. Which species? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function. Appl. Soil Ecol. 10:191–199. https://doi.org/10.1016/S0929-1393(98)00120-6. I examine a number of problems that need to be identified and accounted for when examining the relationships between diversity and ecosystem function. Among these are measures of diversity and complexity in ecosystems: species richness, diversity indices, functional groups, keystone species, connectance, etc, all of which may be difficult to relate to ecosystem function. Several important distinctions, when testing diversity–function relationships empirically, are discussed: Diversity of functional groups, diversity within functional groups vs. total diversity; manipulating variables such as body-size distributions vs. manipulating diversity per se; effects of diversity vs. effects of biomass; and diversity–function relations under stable vs. changing conditions or perturbations. It is argued that for the management and development of sustainable ecosystems, it is probably more important to understand the linkages between key species or functional groups and ecosystem function, rather than focusing on species diversity. This is because there are possible mechanistic relations between what species do in ecosystems and ecosystem function. Diversity, being an abstract and aggregated property of the species in the context of communities and ecosystems, lacks such direct relations to ecosystem functions.

28. Berrie, A.M. and J.V. Cross,. .2007. Producing apples free from pesticide residues. Report of Defra project HH3122STF issued June 2007, 92 pp.

29. Bhandari, G., R.B. Thapa, Y.P. Giri, H.K. Manandhar, D. Lohman, N. Krakhauer, A. Jha, P.k. Jha, N.R. Devkota, P. Thapa and R.A. Mandal. 2017. Maize stem borer, *Chilo partellus* (Swinhoe) distribution along elevational vegetation and climate variability. Maize (*Zea mays* L.) after rice is the second most important crop of Nepal. Maize stem borer, *Chilo partellus* (Swinhoe) is the main polyphagous biotic constraint for the successful cultivation of this crop. Nepalese farmers are very vulnerable to the threats faced by climate change because they rely on weather-dependent rain-fed agricultural systems for their subsistence livelihood. With rise in temperature, the insect-pests are expected to extend their geographic range from tropics and subtropics to temperate regions at higher altitudes along with shifts in cultivation areas of their host plants. There has been reports that the plant damage and grain yield reduction due to this pest ranges 20-87% and 15-60%, respectively. Its total developmental period was 25-30 days and completed 5 generations in a year in Chitwan condition with its high incidence in lower elevation (<600m), followed by mid altitude (600-1500m) and less frequently observed in the higher altitude (1500-1900m and sometimes up to 2088 m altitude. Understanding its biology/phenology with respect to climate change and maize crop growing areas at different altitudes in useful.

30. Bhalla, O.P., Verma, A.K., Dhaliwal, H.S. 1983. Insect visitors of mustard bloom (*Brassica campestres* Var, *sarson*), their number and foraging behavior under mid-hill conditions. Journal of Entomological Research 7:15-17.

31. Bista, S. and G.P. Sivakoti. 2001. Honeybee Flora at Kavre, Dolakha District. J. Nepal Agric. Res. Vol. 4: Adequate knowledge about bee flora is the prerequisite to initiate bee keeping. A study was conducted at Kavre area of Dolakha district during 1997-1999 to identify existing bee flora and develop a floral calendar. Based on the interview with bee farmers and visual observations, 119 important plant species were recorded, out of which 47 species were found major sources for honeybees. Spring season (mid-March to mid-June) and autumn season (mid-Sept to Oct) were identified as honey flow periods having a number of floral plants such as *Guizotia abyssinica*, *Fraxinus floribunda*, *Prunus cerasoides*, *Pyrus communis*, *Castanopsis indica*, *Brassica* spp., *Citrus* spp., *Berberis* spp., *Rubus* spp., *Rhododendron* spp. and *Trifolium* spp. Winter season (mid- Nov to Feb) is the critical dearth period with a few flowering plants like *Reinwardtia indica*, *Pogestemon glaber*, *Caesalpinia* spp. and *Eupatorium* spp. Depending upon the climatic conditions, possibility of planting multipurpose plants has been discussed. Based on available flora, major characteristics of these plant species, utility status and flowering duration a bee floral calendar was developed for Kabre. To conserve these floras, attention must be made to maintain and multiply the existing flora.

32. Björkman, T. 1995. Role of honeybees (Hymenoptera: Apidae) in the pollination of buckwheat in eastern North America. J. Econ. Entomol. 88:1739-1745. Seed production in buckwheat, *Fagopyrum esculentum* Moench, can be lower than expected from the plant biomass. Low seed production is often blamed on inadequate pollination. Honey bees, *Apis mellifera* L., were at least 95% of the insect visitors to buckwheat flowers in fields of central New York State. The number of times each flower was visited by a honey bee ranged from zero to >40, but the number of honey bee visits did not increase daily seed initiation if each flower was visited at least twice. Pollen delivery sometimes limited seed set, but limitation was not associated with low honey bee visitation frequency. The yield and genetic quality of buckwheat is best with pollen deliveries of at least 10 grains, but honey bees (It-livered less pollen. The time between delivery of the 1st and 10th pollen grain was ≍ 1 h, which is more than enough for fertilization to occur. Buckwheat in New York is pollinated primarily by honey bees, but bee behavior is not well adapted to the crop, and the effectiveness of bees as pollinators was not improved at higher bee populations.

33. Bockstael, N. E., A. M. Freeman, R. J. Kopp, P. R. Portney, and V. K. Smith. 2000. On measuring economic values for nature. *Environmental Science & Technology* 34.8: 1384-1389. The authors explained the concept of "values" in so far as it applies to economics, and presented methods to measure the economic values of nature. They explained that the economic value for an ecosystem service relates to the contribution it makes to human well-being.

34. Bohensky, E., and Y. Maru. 2011. Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on "Integration"? Ecology and Society, 16(4), 6. Despite the increasing trend worldwide of integrating indigenous and scientific knowledge in natural resource management, there has been little stock-taking of literature on lessons learned from bringing indigenous knowledge and science together and the implications for maintaining and building social-ecological system resilience. In this paper we investigate: (1) themes, questions, or problems encountered for integration of indigenous knowledge and science; (2) the relationship between knowledge integration and social-ecological system resilience; and (3) critical features of knowledge integration practice needed to foster productive and mutually beneficial relationships between indigenous knowledge and science. We examine these questions through content analyses of three special journal issues and an edited book published in the past decade on indigenous, local, and traditional knowledge and its interface with science. We identified broad themes in the literature related to: (1) similarities and differences between knowledge systems; (2) methods and processes of integration; (3) social contexts of integration; and (4) evaluation of knowledge. A minority of papers discuss a relationship between knowledge integration and social-ecological system resilience, but there remains a lack of clarity and empirical evidence for such a relationship that can help distinguish how indigenous knowledge and knowledge integration contribute most to resilience. Four critical features of knowledge

integration are likely to enable a more productive and mutually beneficial relationship between indigenous and scientific knowledge: new frames for integration, greater cognizance of the social contexts of integration, expanded modes of knowledge evaluation, and involvement of inter-cultural "knowledge bridgers."

35. Bot, A. and J. Benites. 2005. The importance of soil organic matter. Key to drought-resistant soil and sustained food production. Bull FAO N° 80 89–94.

36. Boyd, J., and S. Banzhaf. 2007. What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics* 63.2-3: 616-626. The authors defined ecosystem services as components of nature, directly enjoyed, consumed, or used; they suggested that services are end products of nature. They stated that practical units of measurement are stocks (e.g., number of bees), and that services are spatially explicit.

37. Bradford, M.A. 2014. Good dirt with good friends. Nature 505:486–487. https://doi.org/10.1038/nature12849.

38. Brown, M, and T. Tworkoski. 2004. Pest management benefits of compost mulch in apple orchards. Agric Ecosyst Environ 103:465–472. doi:10.1016/j.agee.2003.11.006. The effect of compost application on weed, fungal, and insect pest management in apple orchards was investigated from 1999 to 2001. Composted poultry manure was applied in June 1999 to half of two small research orchards which had previously received little or no management. The compost provided weed control for 1 year after application. There was no effect of compost on apple scab (*Venturia inaequalis*) infection. In a laboratory experiment, growth of the brown rot fungus (*Monilinia fructicola*) was significantly slower on a compost substrate than a sterilized compost substrate. The compost significantly affected arthropod abundance during two years after application, with more predators and fewer herbivores in the compost treated plots. Populations of spotted tentiform leafminer (*Phyllonorycter blancardella*) and migrating woolly apple aphid (*Eriosoma lanigerum*) nymphs were reduced in the compost plots. This study showed that the use of compost in an orchard ecosystem is beneficial to management of weed, fungal, and insect pests. The use of compost as a mulch in orchard ecosystems should be encouraged as a sustainable management practice because of a potential to reduce pesticide use.

39. Bryan, B. A., C. M. Raymond, N. D. Crossman, and D. H. Macdonald. 2010. Targeting the management of ecosystem services based on social values: Where, what, and how? *Landscape and Urban Planning* 97.2: 111-122. This study used methods from ecology to conduct a spatial analysis for conservation planning that considers social values. According to the authors, biophysical and economic values are mapped for spatial planning, but social values are rarely considered. This study illustrated how identifying and mapping social values might help manage ecosystem services at the landscape level.

40. Busari, M. A., S. S. Kukal, A. Kaur, R. Bhatt, and A.A. Dulazi. 2015. Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research, 3(2), 119–129. https://doi.org/10.1016/j. iswcr.2015.05.002. There is an urgent need to match food production with increasing world population through identification of sustainable land management strategies. However, the struggle to achieve food security should be carried out keeping in mind the soil where the crops are grown and the environment in which the living things survive. Conservation agriculture (CA), practising agriculture in such a way so as to cause minimum damage to the environment, is being advocated at a large scale world-wide. Conservation tillage, the most important aspect of CA, is thought to take care of the soil health, plant growth and the environment. This paper aims to review the work done on conservation tillage in different agro-ecological regions so as to understand its impact from the perspectives of the soil, the crop and the environment. Research reports have identified several benefits of conservation tillage over conventional tillage (CT) with respect to soil physical, chemical and biological properties as well as crop yields. Not less than 25% of the greenhouse gas effluxes to the atmosphere are attributed to agriculture. Processes of climate change mitigation and adaptation found zero tillage (ZT) to be the most environmental friendly among different tillage techniques. Therefore, conservation tillage involving ZT and minimum tillage which has potential to break the surface compact zone in soil with reduced soil disturbance offers to lead to a better soil environment and crop yield with minimal impact on the environment.

41. Cáceres, D. M., E. Tapella, F. Quétier, and S. Díaz. 2015. The social value of biodiversity and ecosystem services from the perspectives of different social actors. *Ecology and Society* 20.1:62. This paper quantified how different social actors perceive the ecosystem services associated with six ecosystem types in Argentina. The authors found that subsistence farmers and extension officers valued more ecosystem services associated with pristine forests than the other social actors. In addition, conservation officers and policymakers identified many more ecosystem services than cattle ranchers and large farmers.

42. Cadotte, M. W., K. Carscadden, and N. Mirotchnick. 2011. Beyond species: Functional diversity and the maintenance of ecological processes and services. *Journal of Applied Ecology* 48.5:1079-1087. The authors made a clear case for using functional diversity instead of species richness when analyzing the relationship between biodiversity and ecosystem functioning. They stated that functional diversity should be incorporated into conservation and restoration analyses and decision making to ensure the maintenance of ecosystem processes and services.

43. Camara, K.M., W.A. Payne, and P.E. Rasmussen. 2003. Long-term effects of tillage, nitrogen, and rainfall on winter wheat yields in the Pacific Northwest. Agron. J, 95, 828–835. https://doi.org/10.2134/agronj2003.8280. Sustainable cropping systems are essential for agronomic, economic, and environmental reasons. Data from a winter wheat (*Triticum*

aestivum L.)/summer fallow rotation experiment, in eastern Oregon, was used to evaluate long-term effects of tillage, N, soil depth, and precipitation on yield. The soil is a Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll). The experiment consisted of three tillage treatments (moldboard plow, offset disk, and subsurface sweep) and six N treatments. Four main time periods (1944–1951, 1952–1961, 1962–1987, 1988–1997), were identified, within which experimental treatments were consistently maintained. Depth to bedrock ranged from 1.2 to 3.0 m. Yield was significantly greater (>300 kg ha^{-1}) for the moldboard plow than for the subsurface sweep in all time periods. Yield was generally greater (>100 kg ha^{-1}) for the moldboard plow than for the offset disk, but only significantly in Time Periods 3 and 4. For Periods 1 and 2, the addition of N fertilizer tended to produce higher yields, regardless of quantity or distribution of rainfall. For Period 3, yield did not increase with the addition of more than 45 kg N ha^{-1}, which we attribute to below-normal precipitation. For Period 4, when precipitation was above average, yield increased with the addition of up to 90 kg N ha^{-1}. Results demonstrated that despite beneficial effects on soil properties, conservation tillage has tended to be less productive for this cropping system than moldboard plowing, probably due to lack of downy brome weed control in the conservation tillage systems.

44. Campbell, C.G. 1997. Buckwheat *Fagopyrum esculentum* Moench. Institute of Plant Genetics and crop Plant Research, Gatersleben / International Plant Genetic Resources Institute,, Rome, Italy.

45. Canali, S., G. Roccuzzo, F. Tittarelli, C. Ciaccia, S. Fiorella, and F. Intrigliolo. 2012. Organic Citrus: Soil Fertility and Plant Nutrition Management. In: Srivastava A. (eds) Advances in Citrus Nutrition. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-4171-3_24. During the last decade, the organic food and farming (OFF) sector has grown considerably worldwide. Citrus play an important role in organic farming systems, being one of the most highly demanded products on the market for organic produce. In this chapter, the criteria for citrus orchards fertility management and plant nutrition in the organically managed agroecosystems are discussed in the light of the most relevant scientific literature. Moreover, two case studies carried out in Southern Italy and aimed at comparing conventional and organic orange management in terms of yield, yield quality and long-term impact on soil fertility are reported. The body of knowledge available and the results presented demonstrate that organic citrus management is a technically feasible option for citrus growers. In addition, the shift to organic farming could contribute to enhance the environmental sustainability of citrus productions in the long term.

46. Canali, S. A. Trinchera, F. Intrigliolo, L. Pompili, L. Nisini, S. Mocali, and B. Torrisi. 2004. Effect of long term addition of composts and poultry manure on soil quality of citrus orchards in Southern Italy. Biol. Fertil. Soils 2004, 40, 206–210. https://doi.org/10.1007/s00374-004-0759-x. A 6-year study was conducted in an organically managed orange orchard located in Sicily (Southern Italy) to assess the effect of compost and organic fertiliser utilisation on soil quality. Adopting a

randomised-block experimental design with three replicates, four treatments were carried out. In treatments 1 and 2, two different composts (C1 from distillery by-products and C2 from livestock waste) were applied. The plots of treatment 3 were fertilised using dried poultry manure. The control treatment was fertilised by mineral/synthetic fertilisers. In order to verify the hypothesis that composts and organic fertilisers improve soil fertility, soil quality was evaluated by selecting dynamic soil parameters, as indicators linked to C and N cycles. Total organic C, total N, C/N ratio, humified fraction, isoelectric focussing (IEF) of extracted organic matter, microbial biomass C, potentially mineralisable N under anaerobic conditions, potentially mineralisable C, C mineralisation quotient and metabolic quotient were determined for each sample. Moreover, the Community Level Physiological Profile (by Biolog technique) was defined, calculating derived functional biodiversity and versatility indexes. Parameters related to IEF and potentially mineralisable C showed significant differences among the treatments. Moreover, total C, total N and humification parameters tended to increase, while no differences were observed in biodiversity indexes. On these findings, it was concluded that composts and poultry manure only weakly affected soil properties, though they increased soil potentially available nutritive elements to crops.

47. Carpenter, S., E. Bennett, and G. Peterson. 2006. Scenarios for ecosystem services: An overview. *Ecology and Society* 11.1: 29. This paper evaluated the Millennium Ecosystem Assessment scenarios and their implications for the management of ecosystem services. After conducting quantitative and qualitative analyses, the authors concluded that the MEA scenarios are a tool for analyzing trade-offs between ecosystem services and exploring logical consequences for different policies that manage ecosystem services.

48. Carpenter, S. R., H. A. Mooney, J. Agard, *et al*. 2009. Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences* 106.5: 1305-1312. This paper argues that the current science evaluating ecosystem services is fragmented. The authors advocated for science that elaborates on a social-ecological systems approach, claiming that policies and practices for ecosystem services could be enhanced by evaluating the feedbacks between biophysical and social systems.

49. CBS. 2019. Agriculture statistics Nepal. Central Bureau of Statistics, Ramshah Path, Kathmandu, Nepal.

50. Chan, K. M. A., M. R. Shaw, D. R. Cameron, E. C. Underwood, and G. C. Daily. 2006. Conservation planning for ecosystem services. *PLoS Biology* 4.11: 2138-2152. The first incorporation of multiple ecosystem services targets alongside biodiversity in a conservation planning analysis. The case study in the central coast ecoregion of California included crop

pollination, forage production, water provision, carbon storage, outdoor recreation, and flood mitigation alongside biodiversity targets using the Marxan planning tool.

51. Chan, K. M. A., P. Balvanera, K. Benessaiah, et al. 2016. Opinion: Why protect nature? Rethinking values and the environment. *Proceedings of the National Academy of Sciences* 113.6: 1462-1465. The authors argued that conservation has mostly focused on instrumental or intrinsic values of nature, but that it is time to engage with a third class of values that they term relational values. Relational values are preferences, principles, and virtues associated with relationships, both interpersonal and as articulated by policies and social norms, between people and nature**.**

52. Chan, K. M. A., T. Satterfield, and J. Goldstein. 2012. Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics* 74:8-18. The authors argued that the effectiveness of the ecosystem services framework in decision making is hindered by the conflation of services, values, and benefits, and a failure to treat diverse kinds of values. The authors distinguished eight dimensions of values, and proposed a typology for the classification of the nonuse and cultural values of ecosystem services.

53. Ching, L.L. and D. Stabinsky. 2011. Ecological agriculture is climate resilient. In: UN Climate Change Conference November 28-December 9, 2011, Durban, Third World Network Briefing Paper 1. Penang: Third World Network.

54. Choruma, D.J. and O.N. Odume. 2019. Exploring Farmers' Management Practices and Values of Ecosystem Services in an Agroecosystem Context—A Case Study from the Eastern Cape, South Africa. Sustainability 2019, 11, 6567. https://doi.org/10.3390/su11236567. Globally, farmers remain the key ecosystem managers responsible for increasing food production while simultaneously reducing the associated negative environmental impacts. However, research investigating how farmers' agricultural management practices are influenced by the values they assign to ecosystem services is scarce in South Africa. To address this gap, a survey of farmers' agricultural management practices and the values they assigned towards ecosystem services was conducted in the Eastern Cape, South Africa. Results from the survey show that farmers assign a high value on food provisioning ecosystem services compared to other ecosystem services. Irrigation and fertilizer decisions were mostly based on achieving maximum crop yields or good crop quality. The majority of farmers (86%) indicated a willingness to receive payments for ecosystem services (PES) to manage their farms in a more ecosystems-oriented manner. To encourage farmers to shift from managing ecosystems for single ecosystem services such as food provision to managing ecosystems for multiple ecosystem services, market-oriented plans such as PES may be employed. Effective measures for sustainable intensification of food production will depend on the inclusion of farmers in the development of land management strategies and practices as well as increasing farmers' awareness and knowledge of the ecosystem services concept.

55. Ciaccia, C.. A. La Torre, F. Ferlito, E. Testani, V. Battaglia, L. Salvati, and G. Roccuzzo. 2019. Agroecological Practices and Agrobiodiversity: A Case Study on Organic Orange in Southern Italy. Agronomy 2019, 9, 85. https://doi.org/10.3390/agronomy9020085. The integration of Agroecological Service Crops (ASCs) into agroecosystems can provide several ecological services, such as nutrient cycling and disease and weed management. A two-year experiment on an organic orchard was carried out to compare barley (B) and horse bean (HB) ASCs with a control without ASC (Cont) in combination with fertilizers. Their effects on soil fertility and weed- and soil-borne fungi communities were evaluated by direct measurements, visual estimation, and indicators computation. A Principal Component Analysis (PCA) was used to identify latent patterns and redundancy among variables, whereas a correlation analysis was used to discriminate the compared systems within the PCA matrix. The empirical results of this study put in evidence the correlation among soil, weed, and fungal variables. A slight contribution of fertilizers on the system's variability was observed, whereas a clear effect of ASCs was highlighted. The systems differed in weed communities, with the lowest density associated to B and the highest to Cont. B showed the highest fungal diversity, with changes in community compared to HB. HB showed a contribution on soil fertility, being associated to organic matter increase and N availability, and evidencing mixed impacts on soil quality and ecosystem functioning. Overall, the above-ground diversity and below-ground community results were inter-correlated.

56. Collison, C. H. 1973. Nectar secretion and how it affects the activity of honey bees in the pollination of hybrid pickling cucumbers *Cucumis sativus* L. M.Sc. Thesis, Michigan State University, East Lansing, USA.

57. Colloff, M., E. Lindsay, and D. Cook. 2013. Natural pest control in citrus as an ecosystem service: integrating ecology, economics and management at the farm scale. Biol. Control 67:170–77. https://doi.org/10.1016/j. biocontrol.2013.07.017. While we were completing a year-long survey of soil invertebrates in eight citrus orchards in South Australia, there was an outbreak of Kelly's citrus thrips (*Pezothrips kellyanus*). Four growers in our survey reported their orchards were free of thrips, while the others reported suffering serious economic damage. A retrospective analysis, using data from the invertebrate survey, showed that orchards without thrips damage all had dense ground cover (perennial grasses, diverse forbs and with a deep litter layer), whereas orchards with thrips damage all had patchy ground cover (bare mineral soil with scattered annual weeds or a sparse monoculture of lucerne or oats and no litter layer). Orchards with dense ground cover and no thrips damage had far denser populations of predatory mesostigmatid mites (mean 6471 ± 692 m−2 1 SE) compared with orchards with patchy ground cover and thrips damage (1097 ± 126 m−2). Most Mesostigmata (total 17 spp.) were generalist predators, capable of feeding on thrips larvae when they move from the fruit to the soil to pupate. We suggest the absence of thrips damage is causally related to the presence of a diverse, abundant fauna of natural enemies, enhanced by

good quality ground cover habitat and that growers with no thrips damage are benefitting from the ecosystem service of natural pest control. Using three scenarios of increasing severity of thrips damage (10%, 20% and 40%), we estimated the mean value of natural pest control of thrips as an ecosystem service was A$ 2640, A$ 4610 and A$ 8540 per hectare for those orchards that benefited from the service, whereas those orchards that received no such benefit potentially lost A$ 1970, A$ 3260 and A$ 5850 respectively. Our findings led to the planting of improved ground cover as habitat for predators by three growers, and the development of a commercial predator biocontrol agent for thrips by a fourth, based on mites harvested from his orchard. Growers who had effective natural pest control of thrips are more likely to have greater economic resilience in relation to price volatility shocks than those growers who do not benefit from this ecosystem service.

58. Connor, L.J., Martin, E.C. 1969. Honeybee activity in hybrid cucumbers. (*Apis melifera* L.). Entomological Society of America 24:25-26.

59. Costanza, R., R. d'Arge, R. de Groot, and S. Farber. 1998. The value of the world's ecosystem services and natural capital. *Ecological Economics* 25:3-15. The authors estimated the economic value of seventeen ecosystem services for 16 biomes, based on published studies and some original calculations. The estimated value of the world's ecosystems was US$33 trillion per year, and the authors suggested that this is a minimum estimate due to nature's uncertainties.

60. Cross, J,, M. Fountain, V. Marko, C. Nagy. 2015. Arthropod ecosystem services in apple orchards and their economic benefits. Ecol. Entomol. 40:82–96. doi:10.1111/een.12234. Apple is grown as a long-term perennial crop and orchards provide relatively stable ecological habitats. Only a small proportion of the diverse fauna of arthropods that can inhabit the orchard ecosystem are important pests, the majority of species being minor pests, beneficial or benign. In this paper, the interacting ecosystem services provided by five contrasting naturally occurring arthropod groups in cool temperate apple orchards are reviewed, and their economic benefits broadly quantified. These are: The roles of bees and other insects in apple pollination increasing yields and fruit quality, the economic value of which may be significantly underestimated. Naturally occurring, pesticide-resistant phytoseiid predatory mites and their role in regulating phytophagous mites. They eliminate the need for 1–2 acaricide sprays per annum and the risk of acaricide resistance. The earwig *Forficula auricularia* L. and its role in regulating several important apple pests. There is great variability in populations between orchards for reasons not fully understood. It is estimated that *F. auricularia* reduces insecticide applications by 2–3 per annum and reduces pest damage. Mutualism between the common black ant *Lasius niger* (L.) and important pest aphids, the roles of competitors, natural and artificial food sources, and ant exclusion in disrupting mutualism which can foster biocontrol of aphids by generalist predators so greatly reducing the need for sprays. Beneficial epigeic arthropods and their role in predating the soil dwelling life stages of insect pests.

These contribute to the control of pest populations although the level of suppression is not consistent depending on several ecological factors.

61. Dahal, L., Baker, S.L., and Gyawali, B.K., 1995: "Promoting Proper Use of Pesticides use in Nepal", HMG/Ministry of Agriculture/Winrock International, Nepal.

62. Dahal, K.M., B. Poudel, A.P. Poudel, S., Piya, B. Khanal and A.P. timilsina Coll. & Eds). 2019. New agriculture technology. Government of Nepal, NARC Outreach Division, Khumaltar, Lalitpur, Nepal. Agriculture plays an important role in the economic development of Nepal and commercialization of agriculture is our responsibility. This collection and compilation includes newer and improved technologies in agriculture tested by NARC in its outreach program with this compilation in Nepali language for technology transfer to the farmers in Nepal.

63. Daily, G. C. 1997. Introduction: What are ecosystem services? In *Nature's services: Societal dependence on natural ecosystems*. Edited by G. C. Daily, 1-10. Washington, DC: Island Press. This book chapter provided the first clear definition for ecosystem services. It explained that these maintain biodiversity and the production of ecosystem goods, such as seafood, forage, and timber. The authors stated that in addition to the production of goods, ecosystem services are life-support functions such as cleansing, recycling, and renewal, as well as aesthetic benefits.

64. Daily, G. C., S. Polasky, J. Goldstein, et al. 2009. Ecosystem services in decision making: Time to deliver. *Frontiers in Ecology and the Environment* 7.1: 21-28. This article operationalized the concept of ecosystem services to inform decision making. It created a conceptual framework that included the biological (i.e., ecosystems, services) and socioeconomic dimensions of ecosystem services (i.e., values, institutions, decisions).

65. Dale, V.H. and S. Polasky. 2007. Measures of the effects of agricultural practices on ecosystem services. Ecological Economics, 64(2), 286–296. https://doi.org/10.1016/j.ecolecon.2007.05.00. Agriculture produces more than just crops. Agricultural practices have environmental impacts that affect a wide range of ecosystem services, including water quality, pollination, nutrient cycling, soil retention, carbon sequestration, and biodiversity conservation. In turn, ecosystem services affect agricultural productivity. Understanding the contribution of various agricultural practices to the range of ecosystem services would help inform choices about the most beneficial agricultural practices. To accomplish this, however, we must overcome a big challenge in measuring the impact of alternative agricultural practices on ecosystem services and of ecosystem services on agricultural production. A framework is presented in which such indicators can be interpreted as well as the criteria for selection of indicators. The relationship between agricultural practices and land-use change and erosion impact on chemical use is also discussed. Together these ideas form the basis for identifying useful indicators for quantifying the costs and benefits of agricultural systems for the range of ecosystem services interrelated to agriculture.

66. Daniel, T. C., A. Muhar, A. Arnberger, et al. 2012. Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences* 109.23: 8812-8819. This paper stressed the importance for integrating social science methods in the assessment of cultural ecosystem services. The authors linked ecological structures and functions to various cultural ecosystem services.

67. Darwin, C. 1876. *The effects of cross and self fertilization in the vegetable kingdom.* London: Murray.

68. de Bello, F., S. Lavorel, S. Díaz, et al. 2010. Towards an assessment of multiple ecosystem processes and services via functional traits. *Biodiversity and Conservation* 19.10: 2873-2893. This literature review synthesized the available information connecting functional traits with ecosystem processes and services. They introduced the term trait-service clusters to inform decision making regarding the conservation and management of ecosystem services.

69. de Groot, R. S., R. Alkemade, L. Braat, L. Hein, and L. Willemen. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity* 7.3: 260-272. The authors described the main challenges associated with the integration of ecosystem services in environmental management, including (1) a lack of indicators to test the capacity of ecosystems to provide services, (2) a lack of methods that apprehend the importance of the value of ecosystem services, and (3) a lack of management institutions that deal with multiple ecosystem services.

70. Demestihas, C., D. Plénet, and M. Génard *et al*. 2017. Ecosystem services in orchards. A review. Agron. Sustain. Dev. 37, 12 (2017). https://doi.org/10.1007/s13593-017-0422-1. Arboriculture must maintain acceptable fruit production levels while preserving natural resources. This duality can be analyzed with the concept of ecosystem service. We reviewed the literature on orchards to explain how ecological functions modified by agricultural practices provide six ecosystem services - fruit production, climate regulation, soil nitrogen availability, water regulation, pest and disease control, and pollination - and which indicators could describe them. The major points are, first, that orchards have a high potential of multiple services. They can sequester from 2.4 to 12.5 t C/ha/year. Their perennial character and multi-strata habitat, as well as the opportunity of creating diversified hedgerows and cover crops in alleys, may contribute to a high level of biodiversity and related services. Second, every service depends on many functions. Fruit yield, which could reach up to 140 t/ha in apple orchards, is increased by light interception, carbon allocation, and nitrogen and water uptake. Third, agricultural practices in orchards have a strong impact on ecosystem functions and, consequently, on ecosystem services. Over-fertilization enhances nitrogen leaching, which reduces soil nitrogen availability for the plant and deteriorates the quality of drained water. Groundcover increases humification and reduces denitrification and runoff, thus enhancing soil

nitrogen availability and water regulation. It also enhances biotic interactions responsible for pest control and pollination. Pruning may increase fruit quality trough a better carbon allocation but decreases pest control by fostering the dynamics of aphids. To study multiple ecosystem services in orchards, we suggest using models capable of simulating service profiles and their variation according to management scenarios. We then refer to the available literature to show that conflicts between provisioning and regulating services can be mitigated by agricultural practices. Improved knowledge of soil processes and carbon balance as well as new models that address multiple services are necessary to foster research on ecosystem service relationships in orchards.

71. Devkota, D.C., K.R.Gosai and D. Devkota. 2017. Economic impact analysis of current climate change variability and future impacts in agricultural sectors of Nepal. Nepal Journal of Environmental Science 591):49-56. Nepal's economy is largely based on agriculture, predominantly small scale farming and about half of which is dependent on natural rainfall in Nepal and is highly climatic sensitive sector. Historically, the sector has been affected by floods, droughts and erratic rainfall. This study focused on the impacts and economic costs of climate change in agriculture and assessed perception of communities of Kaski and Mustang districts on frequency and intensity of hailstorm events over time including their related impacts.

72. Devkota, F. P. 2000. Impacts of bee pollination on the yield of broccoli (*Brassica campestris* var. *botrytis* L.) under Chitwan condition. M. S. Thesis submitted to Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal.

73. Dhakal, G. 2003. Efficiency of *Apis mellifera* L. and *Apis cerana* F. for pollinating mustard and buckwheat. M. Sc. Thesis submitted to Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal.

74. Di Prima, S,, J. Rodrigo-Comino, and A. Novara *et al*. 2018. Soil Physical Quality of Citrus Orchards Under Tillage, Herbicide, and Organic Managements. Pedosphere 28:463–477. https://doi.org/10.1016/S1002-0160(18)60025-6. Soil capacity to support life and to produce economic goods and services is strongly linked to the maintenance of good soil physical quality (SPQ). In this study, the SPQ of citrus orchards was assessed under three different soil managements, namely no-tillage using herbicides, tillage under chemical farming, and no-tillage under organic farming. Commonly used indicators, such as soil bulk density, organic carbon content, and structural stability index, were considered in conjunction with capacitive indicators estimated by the Beerkan estimation of soil transfer parameter (BEST) method. The measurements taken at the L'Alcoleja Experimental Station in Spain yielded optimal values for soil bulk density and organic carbon content in 100% and 70% of cases for organic farming. The values of structural stability index indicated that the soil was stable in 90% of cases. Differences between the soil management practices were particularly clear in terms of plant-available water capacity and

saturated hydraulic conductivity. Under organic farming, the soil had the greatest ability to store and provide water to plant roots, and to quickly drain excess water and facilitate root proliferation. Management practices adopted under organic farming (such as vegetation cover between the trees, chipping after pruning, and spreading the chips on the soil surface) improved the SPQ. Conversely, the conventional management strategies unequivocally led to soil degradation owing to the loss of organic matter, soil compaction, and reduced structural stability. The results in this study show that organic farming has a clear positive impact on the SPQ, suggesting that tillage and herbicide treatments should be avoided.

75. Dias, N.P., M.J. Zotti, P. and Montoya, *et al*. 2018. Fruit fly management research: A systematic review of monitoring and control tactics in the world. Crop Protection 112:187–200. https://doi.org/10.1016/j.cropro.2018.05.019. Several fruit fly species are invasive pests that damage quality fruits in horticultural crops and cause significant value losses. The management of fruit flies is challenging due to their biology, adaptation to various regions and wide range of hosts. We assessed the historical and current approaches of fruit fly management research worldwide, and we established the current knowledge of fruit flies by systematically reviewing research on monitoring and control tactics, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. We performed a systematic review of research outputs from 1952 to 2017, by developing an a priori defined set of criteria for subsequent replication of the review process. This review showed 4900 publications, of which 533 publications matched the criteria. The selected research studies were conducted in 41 countries for 43 fruit fly species of economic importance. Although 46% of the studies were from countries of North America, analysis of the control tactics and studied species showed a wide geographical distribution. Biological control was the most commonly studied control tactic (29%), followed by chemical control (20%), behavioral control, including SIT (18%), and quarantine treatments (17%). Studies on fruit flies continue to be published and provide useful knowledge in the areas of monitoring and control tactics. The limitations and prospects for fruit fly management were analyzed, and we highlight recommendations that will improve future studies.

76. Díaz, S., S. Demissew, J. Carabias, et al. 2015. The IPBES conceptual framework—connecting nature and people. *Current Opinion in Environmental Sustainability* 14:1-16. The articulation of and justification for the IPBES Conceptual Framework, which will orient the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. The framework features a diverse set of conceptualizations of nature and its benefits and associated values, including intrinsic, instrumental, and relational.

77. Didelot, F., L. Brun, and L. Parisi. 2007. Effects of cultivar mixtures on scab control in apple orchards. Plant Pathol 56:1014–1022. doi:10.1111/j.1365-3059.2007.01695.x. The effects of two mixtures of resistant and susceptible apple cultivars on the development of scab caused by

Venturia inequalis were observed in an experimental orchard over four years, initially for two years without fungicides against scab, and subsequently for two years with a moderate fungicide schedule. The row-by-row and within-row mixtures included a susceptible cultivar and a resistant cultivar in equal proportions. Without fungicides, the results showed a significant reduction of disease incidence over both years (7·3 to 21·3%), and severity in the second year (35·4%) in the within-row mixtures, compared to the monoculture of the susceptible cultivar. The best results were obtained when the within-row mixture was associated with moderate fungicide treatments; in this case the reduction in disease incidence reached 75·1% on leaves and 69·7% on fruits during the growth phase. The characteristics of the Venturia inaequalis/Malus × domestica pathosystem and the results obtained in this experiment suggest a moderate but not negligible ability of cultivar mixtures for reducing epidemics of the disease.

78. Elena S. A., Aleksandr L. B. 2000. Bee visitation, nectar productivity and pollen efficiency of common buckwheat. Scientific Research Institute of Groat Crops, Shevchenko St. 13, Kamenets Podolsky, 32316, Ukraine. Fagopyrum 17: 77-80. (Abstract: Common buckwheat is broadly used for honey production in bee-keeping as well as for grain production. Due to its short vegetative period and the possibility of cultivation during the whole non-frost period, common buckwheat can be used as a honey-producing crop. Bees visit buckwheat for the collection of nectar and pollen grains. Honey and pollen efficiency of buckwheat depends on the biological characteristics of cultivated varieties.

79. Engel, S., S. Pagiola, and S. Wunder. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics* 65.4: 663-674. This paper described payments for ecosystem services programs and their scope. It summarized the characteristics of PES programs and how PES compared to other policy instruments. The authors concluded that PES is attractive in situations where ecosystem service providers are poor, marginalized landholders, given the association with the beneficiary- pays rather than the polluter-pays principle.

80. FAO—Food and Agriculture Organization of the United Nations. Integrated Soil and Water Management for Orchard Development. Role and Importance; FAO: Rome, Italy, 2005. Available online: http://www.fao.org/3/a0007e/ a0007e00.htm (accessed on 25 March 2020).

81. FAO. 2014. Local good agriculture practice: Nepal IPM standard. National IPM Program, DOA/PPD, Harihar Bhawan, Lalitpur, Nepal. Local good agricultural practices for national IPM standards are outlined for some vegetable crops with fruits like apple, citrus including tea and ginger.

82. FAO. 2019. The state of the world's biodiversity for food and agriculture In: J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments.

Rome. 572 p. Biodiversity is the variety of life at genetic, species and ecosystem levels. Biodiversity for food and agriculture (BFA) is, in turn, the subset of biodiversity that contributes in one way or another to agriculture and food production. It includes the domesticated plants and animals raised in crop, livestock, forest and aquaculture systems, harvested forest and aquatic species, the wild relatives of domesticated species, other wild species harvested for food and other products, and what is known as "associated biodiversity", the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output. Biodiversity for food and agriculture is indispensable to food security, sustainable development and the supply of many vital ecosystem services. Biodiversity makes production systems and livelihoods more resilient to shocks and stresses, including to the effects of climate change. It is a key resource in efforts to increase food production while limiting negative impacts on the environment. Securing and enhancing the multiple roles of BFA will require sustainable use and conservation of the ecosystems, species and genetic diversity.

83. Free, J.B., Ferguson, A.W. 1979. Foraging of bees on oil-seed rape (*Brassica napus* L) in relation to the stage of flowering of the crop and pest control. Journal of Agricultural Science Cambridge 94:151-154.

84. Free, J.B., Nuttall, P.M. 1968. The pollination of oilseed rape (*Brassica napus*) and the behaviour of bees on the crop. Journal of Agricultural Science Cambridge 71:91-94.

85. Garbach, K., J.C. Milder, M. Montenegro, D.S. Karp and F.A.J. DeClerck. 2014. Biodiversity and ecosystem services in agroecosystem. Elsevier Inc.

86. Garratt, M.P.D., C.L. Truslove, D.J. Coston, R.L. Evans, E.D. Moss, C. Dodson, N. Jenner, J.C. Biesmeijer, and S.G. Potts. 2014. Pollination deficits in UK apple orchards. J Pollinat Ecol 12:9–14. Apple production in the UK is worth over £100 million per annum and this production is heavily dependent on insect pollination. Despite its importance, it is not clear which insect pollinators carry out the majority of this pollination. Furthermore, it is unknown whether current UK apple production, in terms of both yield and quality, suffers pollination deficits and whether production value could be increased through effective management of pollination services. The present study set out to address some of these unknowns and showed that solitary bee activity is high in orchards and that they could be making a valuable contribution to pollination. Furthermore, fruit set and apple seed number were found to be suffering potential pollination deficits although these were not reflected in apple quality. Deficits could be addressed through orchard management practices to improve the abundance and diversity of wild pollinators. Such practices include provision of additional floral resources and nesting habitats as well as preservation of semi-natural areas. The cost effectiveness of such strategies would need to be understood taking into account the potential gains to the apple industry.

87. Giles, K.L., B.P. McCornack, T.A. Royer, and N.C. Elliott. 2017. Incorporating biological control into IPM decision making. Curr. Opin. Insect Sci. 20: 84–89. https://doi.org/10.1016/j.cois.2017.03.009. Of the many ways biological control can be incorporated into Integrated Pest Management (IPM) programs, natural enemy thresholds are arguably most easily adopted by stakeholders. Integration of natural enemy thresholds into IPM programs requires ecological and cost/benefit crop production data, threshold model validation, and an understanding of the socioeconomic factors that influence stakeholder decisions about biological control. These thresholds are more likely to be utilized by stakeholders when integrated into dynamic web-based IPM decision support systems that summarize pest management data and push site-specific biological control management recommendations to decision-makers. We highlight recent literature on topics related to natural enemy thresholds and how findings may allow pest suppression services to be incorporated into advanced IPM programs.

88. Gómez-Baggethun, E., R. de Groot, P. L. Lomas, and C. Montes. 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics* 69.6: 1209-1218. The authors summarized the history of the conceptualization of ecosystem services. The authors argued that the ecosystem services history started with the utilitarian framing of beneficial ecosystem functions as services to increase public interest in biodiversity conservation, and then moved toward the incorporation of ecosystem services into markets and payment schemes.

89. Gomez, C., L. Brun, D. Chauffour, and D. De Le Vallée. 2007. Effect of leaf litter management on scab development in an organic apple orchard. Agriculture, Ecosystems and Environment 118, 249– 55. https://doi.org/10.1016/j.agee.2006.05.025. Ascospores of Venturia inaequalis produced on scabbed leaves in the leaf litter are the main source of primary inoculum, causing infections in apple orchards. The purpose of this 2-year experiment, carried out in a commercial organic orchard, was to assess the effect of combining leaf sweeping from the alleys with leaf ploughing in within the row on scab inoculum and development. In 2003, scab severity was monitored at different distances from the unremoved leaf areas to estimate ascospore spreading. Scab incidence and severity were low in 2003 and high in 2004. At fruit harvest, both years, the leaf litter removal method reduced fruit scab incidence by 82.5% and 54.6% respectively, and fruit scab severity by 74.0% and 67.7%, respectively. Measures of scab lesion gradient indicated that ascospore spreading was not important beyond a 20 m distance from the source. The number of trapped ascospores observed in 2004 in the leaf removal treatment was reduced by 95%. Results from this 2-year experiment showed that leaf litter management by leaf removal allowed a reduction in apple scab inoculum and development and demonstrated the benefit of a complete removal of the leaf litter, when combining leaf sweeping from the alleys with leaf ploughing in within the row.

90. GON. 2018. Nepal's sixth national report to the convention on biological diversity. Government of Nepal, Ministry of Forests and Environment (MoFE), Singh Durbar, Kathmandu, Nepal. The CBD was ratified by Nepalese parliament on November 23, 1993, and enforced in Nepal since February 21, 1994. The revised Nepal's NBSAP for 2014-2020 is a comprehensive framework for translating targets into national action and achieving the nation's goals to conserve the biodiversity. The NBSAP progress has been assessed against 58 national indicators for meeting the 20 Aichi Biodiversity Targets (ABT) under five strategic goals. The assessment reveled that out of 58 targets, 3 (5.2%) targets were achieved before deadline 2020, 12 (20.7%) targets were on track to achieve by 2020, 38 (65.5%) targets were towards progress but at an insufficient rate and there was no overall progress for 5 (8.6%) targets. This report includes findings of the newly formed state level consultation/workshops that had been conducted at all seven states as well as consultation with communities in 26 districts. The 6th National Reporting to the CBD analysis of progress toward international biodiversity targets result suggests that despite accelerating policy and management responses to the biodiversity crisis, political commitment and institutional mainstreaming at the federal, state and local levels are needed to be reflected in improved trend to achieve the ABT by 2020.

91. Goodman, R., Hepworth, G., Kaczynski, P., McKee, B., Clarke, S., Bluett, C. 2001. Honeybee pollination of buckwheat (*Fagopyrum esculentum* Moench cv. Manor). Aust.J.Exp.Agr. 41:1217-1221. The role of honeybees (*Apis mellifera*) in the pollination of buckwheat cv. Manor was studied in a commercial planting at Smeaton, Victoria. Honeybees comprised 80% of all insect visitors to this crop. Other insects included ladybirds (*Coccinella transversalis* and *C. undecimpunctata*), hoverflies (*Meangyna viridiceps*), drone flies (*Eristalis* sp.), blowflies (Calliphoridae), cabbage white butterflies (*Pieris rapae*), small bush flies and native bees. The activity of honeybees and other insects increased seed production from 91.5 g/plot (plots closed to insects) to 180.4 g/plot (plots open to insects).

92. Grafton-Cardwell, E.E., L.L. Stelinski, and P.A. Stansly. 2013. Biology and Management of Asian Citrus Psyllid, Vector of the Huanglongbing Pathogens. Annu. Rev. Entomol 58:413–432. https://doi.org/10.1146/annurev-ento-120811-153542. The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), is the most important pest of citrus worldwide because it serves as a vector of "Candidatus Liberibacter" species (Alphaproteobacteria) that cause huanglongbing (citrus greening disease). All commercially cultivated citrus is susceptible and varieties tolerant to disease expression are not yet available. Onset of disease occurs following a long latent period after inoculation, and thus the pathogen can spread widely prior to detection. Detection of the pathogen in Brazil in 2004 and Florida in 2005 catalyzed a significant increase in research on *D. citri* biology. Chemical control is the primary management strategy currently employed, but recently documented decreases in susceptibility of *D. citri* to several insecticides

illustrate the need for more sustainable tools. Herein, we discuss recent advances in the understanding of *D. citri* biology and behavior, pathogen transmission biology, biological control, and chemical control with respect to “Candidatus Liberibacter asiaticus.” Our goal is to point toward integrated and biologically relevant management of this patho-system.

93. Hamakawa, H. 1986. [Foraging behavior of honeybees (*Apis cerana* and *A. mellifera*) and *Vespula flaviceps* visiting flowers of buckwheat (*Fagopyrum esculentum*). Honeybee Sci. 7:53-56. As many as 3094 specimens of adult citrus pollinators collected from district Haripur represented four orders of insects i.e., Diptera with 16 species, Hymenoptera with 14 species, Lepidoptera with 3 species and Coleoptera with 2 species. The calculated values of relative abundance showed that is most abundant species in ecosystem followed by sp. and . Musca domestica Sarcophaga Apis mellifera. All calculated values of diversity indices except Shannon-H does not show significant difference. Shannon's diversity shows that Naseem Town is most diverse locality then Nikrian B with relative values of 2.213 and 1.136

94. Hauck, J., C. Görg, R. Varjopuro, O. Ratamäki, and K. Jax. 2013. Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives. *Environmental Science & Policy* 25:13-21. This article summarized the policies that address ecosystem services at various levels within the European Union. The authors described two challenges that arose when formulating and implementing policies related to ecosystem services: (1) valuing ecosystem services across scales and (2) analyzing trade-offs that occur when one ecosystem service is preferred over another.

95. Heal, G., G. C. Daily, P. R. Ehrlich, et al. 2001. Protecting natural capital through ecosystem service districts. *Stanford Environmental Law Journal* 20:333-364. This article presented the idea of “ecosystem services districts” as a mechanism to protect ecosystem services. Based on US legislation, the authors stated that there are few explicit protections for ecosystem services because the legal protection of ecosystems was not the primary objective when drafting environmental laws. For example, the Clean Air Act and Clean Water Act were based on health standards, and the Endangered Species Act is species specific.

96. Hirokawa, K. H. 2011. Sustaining ecosystem services through local environmental law. *Pace Environmental Law Review* 28:760-826. The author argued that the value embedded in ecosystem services is relevant to local regulation and local governance. Claiming that the impacts of ecosystem services losses are pronounced at a local level, the author suggested that regulation by local governments may be the most effective way to slow or mitigate such ecosystem services losses.

97. Hondebrink, M.A., L.H. Cammeraat, and A. Cerd`a. 2017. The impact of agricultural management on selected soil properties in citrus orchards in Eastern Spain: A comparison between conventional

and organic citrus orchards with drip and flood irrigation. Sci Total Environ. 581-582: 153–160. The agricultural management of citrus orchards is changing from flood irrigated managed orchards to drip irrigated organic managed orchards. Eastern Spain is the oldest and largest European producer of citrus, and is representative of the environmental changes triggered by innovations in orchard management. In order to determine the impact of land management on different soil quality parameters, twelve citrus orchards sites were selected with different land and irrigation management techniques. Soil samples were taken at two depths, 0–2 cm and 5–10 cm for studying soil quality parameters under the different treatments. Half of the studied orchards were organically managed and the other six were conventionally managed, and for each of these six study sites three fields were flood irrigated plots and the other three drip irrigated systems. The outcome of the studied parameters was that soil organic matter (SOM) and aggregate stability were higher for organic farms. Bulk density and pH were only significantly different for organic farms when drip irrigation was applied in comparison with flooded plots. C/N ratio did not vary significantly for the four treatments. Although there are some points of discussion, this research shows that a combination of different management decisions leads to improvement of a couple of soil quality parameters. Organic management practices were found to be beneficial for soil quality, compared to conventional management for soils with comparable textures and applied irrigation water.

98. Hsieh, F. K., Chen, C. T., Chang, C. P., and Chang, S. Y. 2001. Foraging activities and numerical changes of honeybees on buckwheat, rape, and pear. Plant Prot. Bull. 44: 1-13. The number of *Apis mellifera* foragers peaked between 0930 h and 1130 h at the beginning of buckwheat's blooming season and when buckwheat was in full bloom. However, the highest number of foragers occurred between 0830 h and 1030 h during the late blooming period. Most *A. cerana* foragers appeared before 0930 h with numbers starting decline after 1030 h at each stage of the blooming season of buckwheat. The number of honeybee foragers on Beeline[R]- sprayed buckwheat plots did not show significant difference from the control plot. The total number of grains per buckwheat plant from the Beeline[R]- sprayed plots was significantly higher than that of control plot, but the weight of 1000 grains did not differ. *A. mellifera* foraged the rape before 1130 h, similar to the buckwheat. Most *A. mellifera* foragers on pear flowers were found within 50 m of the beehive, but not more than 150 m. *A. cerana* foragers were not found more than 100 m from the beehive. *A. mellifera* foraged pear flowers mainly for pollen. The percentages of pollen foragers in two tested orchards were 54 % and 46 %, which are respectively 1.4 and 2.7 fold the percentages of the nectar foragers. On the contrary, *A. cerana* foraged mainly for nectar and the population of nectar foragers was two and three folds larger than those of the pollen foragers. The main pollen-foraging activity of *A. mellifera* occurred between 1100 h and 1500 h, but the nectar-foraging activity occurred at 1300 h. The nectar-foraging activity of *A. cerana* mostly occurred between 1500 h and 1700 h.

When the grafted scions of Hosui and Kosui varieties were opened to honeybee pollination, the percentages of fruit setting were 46 % and 78 %, respectively, and each scion could bear an average of 2.2 pears. Hand pollination resulted in 50 % fruit setting and 1-2 pears on each scion. When the *A. mellifera* colonies were placed in a pear surrounded orchard the mean daily number of dead workers (86) was 6 times that of the colonies placed in a relatively isolated orchard. But, there were no differences in the number of dead workers of *A. cerana*, with daily numbers of dead workers between 9 and 10.

99. Hobbs, P.R., K. Sayre, and R. Gupta. 2008. The role of conservation agriculture in sustainable agriculture. Philos. Trans. R. Soc. Lond. B 363:543–55. https://doi.org/10.1098/rstb.2007.2169. The paper focuses on conservation agriculture (CA), defined as minimal soil disturbance (no-till, NT) and permanent soil cover (mulch) combined with rotations, as a more sustainable cultivation system for the future. Cultivation and tillage play an important role in agriculture. The benefits of tillage in agriculture are explored before introducing conservation tillage (CT), a practice that was borne out of the American dust bowl of the 1930s. The paper then describes the benefits of CA, a suggested improvement on CT, where NT, mulch and rotations significantly improve soil properties and other biotic factors. The paper concludes that CA is a more sustainable and environmentally friendly management system for cultivating crops. Case studies from the rice–wheat areas of the Indo-Gangetic Plains of South Asia and the irrigated maize–wheat systems of Northwest Mexico are used to describe how CA practices have been used in these two environments to raise production sustainably and profitably. Benefits in terms of greenhouse gas emissions and their effect on global warming are also discussed. The paper concludes that agriculture in the next decade will have to sustainably produce more food from less land through more efficient use of natural resources and with minimal impact on the environment in order to meet growing population demands. Promoting and adopting CA management systems can help meet this goal.

100. Huang, P.M., Y. Li and M.E. Summer (eds.). 2008. Handbook of soil sciences resource management and environmental impacts. CRC Press, Boca Raton, Florida, USA. It is a comprehensive reference work on the discipline of soil science as practiced today. The new edition has been completely revised and rewritten to reflect the current state of knowledge. It contains definitive descriptions of each major area in the discipline, including its fundamental principles, appropriate methods to measure each property, many examples of the variations in properties in different soils throughout the world, and guidelines for the interpretation of the data for various applications (agricultural, engineering, and environmental impacts.

101. Hummel, R. 2002. Effects of vegetable production system on epigeal arthropod populations. Agric Ecosyst Environ 93:177–188. doi:10.1016/S0167-8809(01)00346-2. Populations of epigeal arthropods were monitored in vegetable production systems under varying degrees of sustainable agricultural practices in Fletcher, NC (USA). Two tillage types (conventional plow and disk, strip-

tillage (ST)), two input approaches (chemically based, biologically based) and two cropping schedules (continuous tomato Lycopersicon esculentum Mill.], 3-year rotation of sweet corn [Zea mays L.]/cabbage [Brassica oleracea L.], cucumber [Cucumis sativus L.]/cabbage and tomato) were employed from 1995–1998. A second study with tomatoes was performed in 1997–1998 to separate effects of pesticide use, intercropping and herbicide application. Pitfall traps (48-h sample period) were used at ~25-day intervals to monitor relative activity of carabid beetles (Coleoptera: Carabidae), staphylinid (Coleoptera: Staphylinidae) beetles and lycosid spiders (Araneidae: Lycosidae). Carabids and lycosids appeared to be more active in systems with ground cover. Trap catches of carabid species were not significantly affected by insecticide input, but trap catches of lycosids were lower in plots with conventional insecticide use. No consistent effect of tillage was found over time, although Scarites spp. were more active in minimally disturbed habitats in 1998. Two distinct patterns of seasonal activity were observed for carabid beetles and lycosid spiders. Ground cover generally enhanced abundance of carabids and lycosids, while tillage type, pesticide use and crop rotation had different effects.

102. IPCC. 2014. Summary for policymakers. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1–32). Cambridge: Cambridge University Press.

103. Inclán, D.J., P. Cerretti, and L. Marini. 2015. Landscape composition affects parasitoid spillover. Agric. Ecosyst. Environ. 208:48–54. https://doi.org/10.1016/j.agee.2015.04.027. The intensification of agriculture has led to a severe simplification of agricultural landscapes, resulting in a marked reduction in the diversity of insect natural enemies. However, how this simplification shapes the movement of insect parasitoids between crop and non-crop habitats (i.e., spillover) is still unclear. We examined the potential spillover of tachinid parasitoids from semi-natural habitats into apple orchards across different landscapes. We sampled commercial apple orchards localized in three landscape types (forest-, grassland- or apple-dominated landscapes) to first evaluate if landscape composition affects the local species richness in apple orchards. Second, we tested whether the contribution of forest and grassland habitats to the local tachinid community composition of apple orchards changes according to landscape composition. We found that landscape composition did not affect local tachinid species richness in apple orchards, while it affected the species spillover. Independently of the landscape, we found highly nested communities of tachinids between apple orchards and forest habitats suggesting a strong spillover of tachinids between these habitats. In contrast, tachinids in apple orchards were nested with grassland habitats only in landscapes dominated by apple orchards. Our results have important implications for the conservation of insect parasitoids in agricultural landscapes, as the spillover

of species in the crop can be affected by the type and the area of semi-natural habitats in the surrounding landscape.

104. Jackson, S., and L. R. Palmer. 2015. Re-conceptualizing ecosystem services: Possibilities for cultivating and valuing the ethics and practices of care. *Progress in Human Geography* 39.2:122-145. The authors rejected the conventional notion of payments for ecosystem services (PES) as either an economic or an environmental strategy. They suggested that nature is valued in so far as it relates to actual human and nonhuman interrelations and practices, and that the relationship between people and nature should be the valued stock instead of the "fixed stock of ecosystem services.

105. Jha, P. and M. Sivakoti. 2017. Climate change and biodiversity in Nepal. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. Biodiversity and climate are interconnected and climate change has been widely recognized as one of the serious threats to organisms. This negative consequences of climate change are drawing more attention and are linked with human health, ecosystem service and livelihood. Nepal having the diverse climate and varied biodiversity, is one of the countries vulnerable to climate change.

106. Jha, P.K., R.B. Thapa and J.B. Shrestha. 2005. Conservation and management of pollinators for sustainable agriculture through an ecosystem approach. Final report submitted to FAO Nepal, Pulchowk, Lalitpur, Nepal. Plants and animal species have been taxonomically studied in Nepal, but very little work exists on mutualistic contribution as pollination and pollinators. Insects, birds and mammalian species have been acting as pollinating agents in nature. There are 8724 species of insects, 181 species of mammals and 861 species of birds reported from Nepal. Out of these, insects are the major pollinators followed by birds, and a very few mammals. There is a high probability of new records of pollinating insects from Nepal. It is believed that Hymenopteran insects are important pollinators but insufficiently explored in Nepal. Honey bees contribute significantly in pollination of crops and wild plants, and Nepal is one of the countries rich in honeybee species. There are five species of bees indigenous to Nepal, and in addition to those, one exotic species, European honey bee *Apis mellifera* L. has been successfully introduced (in Nepal) in the 1990s through India, and now its population dominates in many areas. Some bird species have been recorded as good pollinators, but habitat destruction is believed to affect the population of such birds. There exist a few studies on the bee flora and pollens in Nepal. About 300 plant species have been studied for their pollen structure and taxonomy. Studies indicate decline in pollinators in some of the areas. Habitat loss, high rate of deforestation, increasing use of pesticides and growing pollution, climate change, introduction of new species (e.g. *Apis mellifera* L.), and low level of awareness about pollinators, lack of emphasis upon pollinators are some major causes that have been identified to affect the population of pollinators. Conservation of pollinators has

not been given due attention in Nepal, and efforts to conserve biological diversity in the ecosystems have directly and indirectly conserved pollinators. There are 16 protected areas covering 18.36% of Nepalese land and protects biodiversity. In the last few years, Nepal has given emphasis on integrated pest management, which can protect pollinators to some extent. Bee keeping is popular in many areas. It has played an important role in conservation of pollinators. There are over a dozen publications that can be used as pollinators catalogues. Entomology Division of NARC has an insect museum having 1863 species of insects, Natural History Museum of Tribhuvan University houses over 1000 species of insects, birds and mammals. Annapurna Regional Museum, Pokhara houses a very good collection of butterflies. Two useful electronic flora databases (Medicinal and Aromatic Plant Database of Nepal, MAPDON and Floral Database of Nepal, FLODON) have been developed by Central Department of Botany, T.U. in collaboration with Ethno-botanical Society of Nepal (ESON) and Natural History Museum, London. The present report includes a list of global and regional networks and initiatives on pollinators as well as concerned institutions in Nepal. A list of relevant laws, regulation, policies and plans have also been analyzed with brief description of important policies and strategies (Agriculture Perspective Plan, Nepal Biodiversity Strategy, National Agriculture Policy, Periodic Plans, Nepal Environmental Policy and Action Plan), and market related acts and laws. There is a need to document traditional knowledge about pollinators. Traditional knowledge about honeybees has been recorded by a few workers in Nepal. The knowledge about Apitherapy, traditional treatment of bee diseases, local hive preparation and management of honeybees, and bee flora that provide pollen and nectar are recorded by few workers. Teaching and training on pollinators and pollination biology are relatively inadequate, and there is a need to develop human resources, particularly taxonomists and ecologists, and to aware people about the important component of ecosystem. Over two hundred references have been listed related with pollens, taxonomy, beekeeping, pollination, bee flora, and pollinators.

107. Joshi, B.K., A.K. Acharya, D. Gauchan and P. Chaudhary. 2017. The state of Nepal's biodiversity for food and agriculture. Ministry of Agricultural Development, Kathmandu, Nepal. Biodiversity underpins the livelihoods and wellbeing of humankind on earth. Not all nations are fortunate to enjoy rich biodiversity, but Nepal, despite being a small country, harbors world's 3.2% flora and 1.1% fauna, ranks the 31st richest country in the world and 10th in Asia in terms of biodiversity. A total of 284 flowering plants, 160 species of animals, one species of bird, and 14 species of herpeto fauna are endemic to Nepal. Astonishingly varied geographic, ecological, climatic, socioeconomic, and cultural factors are making possible such a tremendous biodiversity to exist. A large number of biodiversity is useful for food and agriculture and they are grouped as crop, livestock, aquatic, forest and associated biodiversity. A large number of local varieties of crops and vegetables, livestock breeds, fish species, and wild edible species are eroding from their

habitats and growing environments. Introduction of new technologies including varieties, erosion of traditional knowledge, poor utilization of local landraces, lack of proper policies, and poor implementation of policies are key underlying factors contributing to genetic erosion. The Government of Nepal has made several initiatives in collaboration with relevant stakeholders to formulate and revise policies, facilitate conservation and utilization of agro-biodiversity, document information and knowledge.

108. Kamler, F., Pasakova, I. 1987. Pollinationof winter rape (*Brassica napus* var. *arvensis*) and the setting of pods. Pages 337-339. 31st International Apicultural Congress of Apimondia Warsaw 1987. Apimondia Publishing House, Bucharest.

109. Kapil, R.P., Grewal, G.S., Kumar, S., Atwal, A.S. 1971. Insect pollinators of rape seed and mustard. Indian J.Ent. 33:61-66.

110. Kardol, P., W.N. Reynolds, R.J. Norby, and A.T. Classen. 2011. Climate change effects on soil microarthropod abundance and community structure. Applied Soil Ecology, 47(1), 37–44. https://doi.org/10.1016/j. apsoil.2010.11.001. Long-term ecosystem responses to climate change strongly depend on how the soil subsystem and its inhabitants respond to these perturbations. Using open-top chambers, we studied the response of soil microarthropods to single and combined effects of ambient and elevated atmospheric [CO2], ambient and elevated temperatures and changes in precipitation in constructed old-fields in Tennessee, USA. Microarthropods were assessed five years after treatments were initiated and samples were collected in both November and June. Across treatments, mites and collembola were the most dominant microarthropod groups collected. We did not detect any treatment effects on microarthropod abundance. In November, but not in June, microarthropod richness, however, was affected by the climate change treatments. In November, total microarthropod richness was lower in dry than in wet treatments, and in ambient temperature treatments, richness was higher under elevated [CO2] than under ambient [CO2]. Differential responses of individual taxa to the climate change treatments resulted in shifts in community composition. In general, the precipitation and warming treatments explained most of the variation in community composition. Across treatments, we found that collembola abundance and richness were positively related to soil moisture content, and that negative relationships between collembola abundance and richness and soil temperature could be explained by temperature-related shifts in soil moisture content. Our data demonstrate how simultaneously acting climate change factors can affect the structure of soil microarthropod communities in old-field ecosystems. Overall, changes in soil moisture content, either as direct effect of changes in precipitation or as indirect effect of warming or elevated [CO2], had a larger impact on microarthropod communities than did the direct effects of the warming and elevated [CO2] treatments. Moisture-induced shifts in soil microarthropod abundance and community

composition may have important impacts on ecosystem functions, such as decomposition, under future climatic change.

111. Kareiva, P., H. Tallis, T. H. Ricketts, G. C. Daily, and S. Polasky. 2011. *Natural capital: Theory & practice of mapping ecosystem services*. Oxford: Oxford Univ. Press. A comprehensive treatment of ecosystem service analysis from the perspective of the InVEST tool for Integrated Valuation of Ecosystem Services and Tradeoffs, of the Natural Capital Project.

112. Karp, D.S., R. Moses, S. Gennet, M.S. Jones, and S. Joseph, *et al*. 2016. Agricultural practices for food safety threaten pest control services for fresh produce. J. Appl. Ecol. 53:1402–12. https://doi.org/10.1111/1365-2664.12707. Over the past decade, several foodborne disease outbreaks provoked widespread reforms to the fresh produce industry. Subsequent concerns about wildlife vectors and contaminated manures created pressure on growers to discontinue use of manure-based composts and remove nearby semi-natural vegetation. Despite widespread adoption, impacts of these practices on ecosystem services such as pest control have not been assessed. We used a landscape-scale field experiment to quantify associations between compost applications, semi-natural vegetation, pest control services and lettuce yields on organic farms throughout California's Central Coast, a region experiencing food safety reforms. We found that farms with surrounding semi-natural vegetation supported a diverse arthropod assemblage, whereas a herbivore-dominated assemblage occupied farms in simplified landscapes. Moreover, predatory arthropods consumed more herbivores at sites with more surrounding non-crop vegetation and reduced aphid pest infestations in lettuce. Compost improved lettuce yields by increasing soil nutrients and organic matter, but affected neither pest control nor Escherichia coli prevalence. Synthesis and applications. Food safety concerns are prompting practices that simplify farms and landscapes. Our results demonstrate that two practices – elimination of manure-based composts and removal of non-crop vegetation – are likely having negative impacts on arthropod biodiversity, pest control and soil quality. Critically, our findings and previous research suggest that compost can be applied safely and that habitat removal is likely ineffective at mitigating food safety risk. There is thus scope for co-managing fresh produce fields for food safety, ecosystem services, and biodiversity through applying appropriately treated composts and stopping habitat removal.

113. Kenter, J. O. 2016. Editorial: Shared, plural, and cultural values. *Ecosystem Services* 21 (Part B): 175-183. This is an editorial that introduced the special issue of *Ecosystem Services*, which arose from the UK National Ecosystem Assessment (2012–2014). The author raises awareness on shared and cultural values. Shared values are considered as the values we hold in common that communities and societies formed through a long-term process of socialization. Cultural values are considered as the values that reflect the importance of culture in managing and valuing ecosystems.

114. Kevan, P.G., Eisikowitch, D. 1990. The effects of insect pollination on canola (*Brassica napus* L. cv. O.A.C. Triton) seed germination. Euphytica 45.

115. Kibblewhite MG, Ritz K, Swift MJ. 2008. Soil health in agricultural systems. Philos. Trans. R Soc. Lond. B 363:685–701. https://doi.org/10.1098/rstb.2007.2178. Soil health is presented as an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support both the agricultural production and the provision of other ecosystem services. The major challenge within sustainable soil management is to conserve ecosystem service delivery while optimizing agricultural yields. It is proposed that soil health is dependent on the maintenance of four major functions: carbon transformations; nutrient cycles; soil structure maintenance; and the regulation of pests and diseases. Each of these functions is manifested as an aggregate of a variety of biological processes provided by a diversity of interacting soil organisms under the influence of the abiotic soil environment. Analysis of current models of the soil community under the impact of agricultural interventions (particularly those entailing substitution of biological processes with fossil fuel-derived energy or inputs) confirms the highly integrative pattern of interactions within each of these functions and leads to the conclusion that measurement of individual groups of organisms, processes or soil properties does not suffice to indicate the state of the soil health. A further conclusion is that quantifying the flow of energy and carbon between functions is an essential but non-trivial task for the assessment and management of soil health.

116. Kinzig, A. P., C. Perrings, F. S. Chapin, et al. 2011. Paying for ecosystem services—promise and peril. *Science* 334.6056: 603-604. The authors summarized the promises and limitations of the payment for ecosystem services schemes. They stated that markets are useful for addressing environmental issues, but are not a panacea. Effective mechanism design requires a deep understanding of the linkages between biodiversity, ecosystem functions, and ecosystem services. Moreover, they listed four mechanisms that protect ecosystem services: (1) regulation and penalty, (2) cap and trade, (3) direct payments, and (4) self-regulation.

117. Kopelkievskii, G.V. 1960. Bees and the buckwheat seed crop. Pchelovodstvo Mosk. 37:36-39.

118. Kopelkievskii, G.V. 1976. [Honeybee (pollination) and seed production of buckwheat.]. Neunylov et al.(eds) Genetika, selektsiia, semenovodstvo i vozdelyvanie grechikhi.171-180.

119. Kovács-Hostyánszki, A., Z. Elek, K. Balázs, C. Centeri, E. Falusi, P. Jeanneret, K. Penksza, L. Podmaniczky, O. Szalkovszki, and A. Báldi. 2013. Earthworms, spiders and bees as indicators of habitat quality and management in a low-input farming region—A whole farm approach. Ecological Indicators, 33, 111–120. https://doi.org/10.1016/j. ecolind.2013.01.033. The benefits of low input farming on biodiversity and ecosystem services are already well-established, however most of these studies focus only on the focal field scales. We aimed to study whether these benefits exist at the whole farm scale, to find the main environmental driving effects on biodiversity at the

whole farm scale in farms of different grassland grazing intensity, applying three well-known species diversity indicator groups of different ecological traits. Edaphic (earthworms), epigeic (spiders) and flying (bees) taxa were sampled in each identified habitat type within 18 low-input farms in Central Hungary, 2010. The number of habitat types, the number of grassland plots, the cumulative area of grasslands and habitat type had an effect on the species richness and abundance of spiders, while grassland grazing intensity influenced the species richness of bees. Both bees and spiders were sensitive to vegetation and weather conditions, resulting in more bees on flower-rich farms and those having higher temperature; and more spiders on farms with more heterogeneous vegetation structure and in low-wind areas. Relatively few earthworms were found in the whole study, and their abundance was not influenced by any of the farm composition and management variables. We conclude that local field management (grazing intensity of grassland patches) can have a farm scale effect, detectable on species diversity indicators that have high dispersal ability and strong connection to grasslands as important foraging sites (bees). However, other farmland biota (spiders) is also strongly determined by farmland composition and habitat diversity, therefore the maintenance of a mosaic within-farm habitat structure is strongly recommended. The application of earthworms as farmland composition or management indicators is strongly restricted because of their special needs of soil conditions.

120. Kremen, C. 2005. Managing ecosystem services: What do we need to know about their ecology? *Ecology Letters* 8.5: 468-479. The author introduced a conceptual framework with four components for linking biodiversity with ecosystem services: (1) identifying the ecosystem service providers, (2) determining community structure that influences functions in landscapes, (3) assessing environmental factors that influence service provisioning, and (4) assessing the spatiotemporal scale over which providers and services operate.

121. Lant, C. L., J. B. Ruhl, and S. E. Kraft. 2008. The tragedy of ecosystem services. *BioScience* 58.10: 969-974. The authors stated that managing ecosystem services reflects the tragedy of the commons. They stated that ecosystem services fell in a social trap due to the institutions that govern them and the law that applies to them (for example, property law reinforcing privatization). This paper presented some ideas on how to better manage and address the administration of ecosystem services, for example via ecosystem services districts.

122. Lipper, L. N. McCarthy, D. Zilberman, S. Asfaw and G. Branca (eds.). 2018. Climate smart agriculture building resilient to climate change. FAO, Rome Italy. Eradicating poverty, ending hunger, and taking urgent action to combat climate change and its impacts are three objectives the global community has committed to achieving by 2030 by adopting the sustainable development goals. Climate change however is expected to act as an effective barrier to agricultural growth in many regions, especially in developing country contexts heavily dependent on rain-fed agriculture. FAO is actively working to support countries in grappling with the challenge of managing

agriculture to reduce hunger and poverty in an increasingly climate constrained world. FAO launched the concept of climate smart agriculture (CSA) in 2009 to draw attention to linkages between achieving food security and combating climate change through agricultural development, and the opportunities for attaining large synergies in doing so. This book elucidates concepts, principles and cases of climate smart agriculture including policy issues.

123. Lichtenberg, E.M., C.M. Kennedy, C. Kremen, P. Batáry, F. Berendse, *et al*. 2017. A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes. Glob. Change Biol. 23:4946–57. https://doi.org/10.1111/gcb.13714. Agricultural intensification is a leading cause of global biodiversity loss, which can reduce the provisioning of ecosystem services in managed ecosystems. Organic farming and plant diversification are farm management schemes that may mitigate potential ecological harm by increasing species richness and boosting related ecosystem services to agroecosystems. What remains unclear is the extent to which farm management schemes affect biodiversity components other than species richness, and whether impacts differ across spatial scales and landscape contexts. Using a global metadataset, we quantified the effects of organic farming and plant diversification on abundance, local diversity (communities within fields), and regional diversity (communities across fields) of arthropod pollinators, predators, herbivores, and detritivores. Both organic farming and higher in-field plant diversity enhanced arthropod abundance, particularly for rare taxa. This resulted in increased richness but decreased evenness. While these responses were stronger at local relative to regional scales, richness and abundance increased at both scales, and richness on farms embedded in complex relative to simple landscapes. Overall, both organic farming and in-field plant diversification exerted the strongest effects on pollinators and predators, suggesting these management schemes can facilitate ecosystem service providers without augmenting herbivore (pest) populations. Our results suggest that organic farming and plant diversification promote diverse arthropod meta communities that may provide temporal and spatial stability of ecosystem service provisioning. Conserving diverse plant and arthropod communities in farming systems therefore requires sustainable practices that operate both within fields and across landscapes.

124. Loreau, M., S. Naeem, P. Inchausti, et al. 2001. Biodiversity and ecosystem functioning: Current knowledge and future challenges. *Science* 294.5543: 804-808. This paper analyzed the relationship between ecological performance and diversity at different scales. They stated that while experiments have showed a positive linear relationship between species richness and ecological performance, scaling up to regional scales remains elusive. Species-area relations imply that the long-term maintenance of diversity at local scales requires a much higher diversity at regional scales.

125. Luck, G. W., G. C. Daily, and P. R. Ehrlich. 2003. Population diversity and ecosystem services. *Trends in Ecology & Evolution* 18.7: 331-336. The authors advocated for a more integrative approach for assessing biodiversity decline. They argued that considering population size, distribution, genetic differentiation, and population density are key to reflect the changes to biodiversity and the effects on ecosystem service provisioning.

126. Luck, G. W., R. Harrington, P. A. Harrison, et al. 2009. Quantifying the contribution of organisms to the provision of ecosystem services. *BioScience* 59.3: 223-235. The purpose of this paper was to elaborate on the unit concept of ecosystem service providers. The authors introduced the concept of a continuum between service providing units and ecosystem service providers (SPU-ESP continuum).

127. Luck, G., K. M. A. Chan, U. Eser, et al. 2012. Ethical considerations in on-ground applications of the ecosystem services concept. *BioScience* 62.12: 1020-1029. The first comprehensive consideration of ethical implications of a diverse set of applications of the ecosystem services concept, including as a communication tool, for policy guidance and priority setting, and for designing economic instruments for conservation. Concerns discussed include the anthropocentric framing, economic metaphor, monetary valuation, commodification, sociocultural impacts, changes in motivations, and equity implications.

128. Mahamood, R., W. Ahmad, M.K. Rafique, G. Sarwar and A. Shahzad. 2017. Pakistan J. Zool. 49(3):897-903. Pollination deficit in apple orchards at Murree, Pakistan. A study was conducted in twenty different managed and unmanaged apple orchards of Murree for determining relationship of different pollinator groups with crop yield. Apple is dependent on insect pollinators to set fruit. Farmers in Pakistan are generally not aware of pollination needs of apple. Results depicted a high population decline of Syrphids and Non-Apis bees. Syrphids were recorded as 12.65 to 13.85 per 250 flowers in 2013 but decreased in year 2014 by 7.82 to 7.88 per 250 flowers and Non-Apis bees was recorded as 6.15 to 7.59 per 250 flowers in 2013 which also decreased and recorded as 5.35 to 5.70 per 250 flowers in year 2014. The results showed the trends of increase in population of *Apis mellifera* and *Apis cerana* between 8.22 to 11.5 per 250 flowers in 2013 as compared to 1.12 to 13.92 per 250 flowers in 2014, whereas population of indigenous *Apis cerana* varied between 3.80 to 5.44 h per 250 flowers in 2013 as compared to year 2014 where it was recorded as 4.34 to 5.56 honey bees per 250 flowers. Apple fruits yield per tree ranged between 214.56 to 218.64 in 2013 and 2014 respectively. Average fruit weight varied between 124.84 to 127.34 g, average number of seeds varied between 7.95 to 7.73 seeds per fruit and yield per tree was recorded between 28.92 to 31.65 kg per tree. Number of Apple fruits per tree ranged between 145.72 to 164.58 in 2013 and 2014, respectively. Average fruit weight varied between 103.66 to 112.13 g and average number of seeds varied between 7.73 to 7.95 seeds per fruit and yield per tree was recorded between 17.34 to 21.78 kg per tree. Eighteen different species were recorded

under 16 genus and 07 families. *Ceratina hieroglyphica*, *Halictus subauratus*, *Osmia caerulescens* were reported first time from Pakistan.

129. Martín-López, B., C. Montes, and J. Benayas. 2007. The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation* 139.1-2: 67-82. The authors explored attitudes toward biodiversity using a contingent valuation survey in the Doñana National Park in Spain. Their analyses showed that willingness to pay for the conservation of biodiversity was associated with affective factors, rather than ecological factors. People valued species that were phylogenetically closer to humans and those that provided utilitarian values to humans, and perceived less value in species important for ecosystem functioning.

130. Mel'nichenko, A.N. 1962. Biological basis for increasing the yield of buckwheat by different sowing dates and degrees of saturation of bee pollination. Uchen.Zap.Gorkov.Univ. 55:5-43.

131. Mesquida, J., Renard, M. 1978. Entomophilous pollination of male-sterile strains of winter rapeseed (*Brassica napus* L Metzger var. *oilfera*) and a preliminary study of alternating devices. 4th International Symposium on Pollination. Maryland Agricultural Experimental Station Miscellaneous Publication . pp. 49-57.

132. Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being. Washington, DC: Island Press. This report from a major international assessment process defined ecosystem services as “the benefits people obtain from ecosystems” (p. V) and defined four categories of ecosystem services (i.e., provisioning, supporting, regulating, and cultural). This report analyzed the state of the earth’s ecosystems and ecosystem services in the period from 2001 to 2005. The analysis showed that 60 percent of ecosystem services (including 70 percent of cultural ecosystem services) have been degraded.

133. Miñarro, M., and E. Prida. 2013. Hedgerows surrounding organic apple orchards in north-west Spain: potential to conserve beneficial insects. Agric For Entomol 15:382–390. doi:10.1111/afe.12025. Flowering plant species in hedgerows may be food sources for beneficial insects and therefore play a role in biodiversity conservation and agroecosystem functioning. Research was conducted in eight organic cider-apple orchards in Asturias (north-west Spain) aiming to (i) identify the native flowering plants in the surrounding hedgerows and (ii) assess the attractiveness of those flowers for beneficial insects, such as pollinators and natural enemies of pests. A total of 7745 flowers belonging to 63 plant species were recorded in the hedgerows from May to September 2012. Flower abundance and species richness decreased as the season progressed. Orchard differences were observed for plant species richness but not for the total number of flowers in the hedgerows, likely as a result of similar management among orchards. Hymenoptera pollinators (honey bees, bumblebees and wild bees) accounted for 37.8% of the total insects recorded visiting flowers, whereas predatory hoverflies (14.9%) were the dominant natural

enemies. The attractiveness for insects was assessed for 21 of the flowering plant species identified in the hedgerows. Flowering plants differed in the number of taxa that they attracted and in their attractiveness for particular insect groups and for insects as a whole. The present study described the floral composition of the hedgerows that surround apple orchards and identified the local floral resources that could provide benefits for farmers by improving ecosystem services of pollination and biological control of pests.

134. Mohr, N.A., Jay, S.C. 1990. Nectar production of selected cultivars of *Brassica campestris* L. and *Brassica napus* L. J.Apic.Res 29:95-100.

135. Montanaro, G., C. Xiloyannis, V. Nuzzo, and B. Dichio. 2017. Orchard management, soil organic carbon and ecosystem services in Mediterranean fruit tree crops. Sci Hortic 217:92–101. doi:10.1016/j.scienta.2017.01.012. Agriculture is not only appointed to produce food but has the potential to provide a range of ecosystem services (ES) depending on the management options adopted at field scale. Information on the impact of management practices adopted in fruit tree crops on ES is fragmented and often not fully codified. This paper focuses on some Mediterranean fruit tree crops i.e. peach (Prunus persica), apricot (Prunus armeniaca), olive (Olea europaea) groves and vineyards (Vitis vinifera), and links mainly soil processes and functions to the provisioning, regulating and sociocultural ES. The effects of field practices (e.g., tillage/no-tillage, cover crops, retention/burning of pruning residues, mineral/organic fertilization) on manageable soil properties (e.g., porosity, organic carbon content, composition of microbial community) and related functions (e.g., supply of nutrients, water storage, soil stability, above-ground biodiversity) were examined. The analysis draws the attention to the pivotal role of the soil organic carbon (SOC) stocks on soil aggregates and erodibility, soil water storage, use of fresh water for irrigation, plant nutrition, biodiversity, nutrient storage and absorption of pesticides. Sociocultural services delivered by tree crops are also discussed. This paper highlights the dependence of ES on the sustainable field practices adopted, particularly those aimed at increasing SOC stocks (e.g., no tillage, increased carbon input, recycling of pruning residuals, cover crops). The outcomes presented may strengthen the significance of increasing SOC management practices for fruit tree crops and be supportive of the implementation of environmentally friendly policies assisting in the conservation or the improvement of the soil natural capital.

136. Monzo, C., and P.A. Stansly. 2017. Economic injury levels for Asian citrus psyllid control in process oranges from mature trees with high incidence of huanglongbing. PLoS ONE 12(4): e0175333. https://doi.org/10.1371/journal. pone.0175333. The Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama, is the key pest of citrus wherever it occurs due to its role as vector of huanglongbing (HLB) also known as citrus greening disease. Insecticidal vector control is considered to be the primary strategy for HLB management and is typically intense owing to the severity of this disease. While this approach slows spread and also decreases severity of HLB once

the disease is established, economic viability of increasingly frequent sprays is uncertain. Lacking until now were studies evaluating the optimum frequency of insecticide applications to mature trees during the growing season under conditions of high HLB incidence. We related different degrees of insecticide control with ACP abundance and ultimately, with HLB-associated yield losses in two four-year replicated experiments conducted in commercial groves of mature orange trees under high HLB incidence. Decisions on insecticide applications directed at ACP were made by project managers and confined to designated plots according to experimental design. All operational costs as well as production benefits were taken into account for economic analysis. The relationship between management costs, ACP abundance and HLB-associated economic losses based on current prices for process oranges was used to determine the optimum frequency and timing for insecticide applications during the growing season. Trees under the most intensive insecticidal control harbored fewest ACP resulting in greatest yields. The relationship between vector densities and yield loss was significant but differed between the two test orchards, possibly due to varying initial HLB infection levels, ACP populations or cultivar response. Based on these relationships, treatment thresholds during the growing season were obtained as a function of application costs, juice market prices and ACP densities. A conservative threshold for mature trees with high incidence of HLB would help maintain economic viability by reducing excessive insecticide sprays, thereby leaving more room for non-aggressive management tools such as biological control.

137. Morandin, L.A., Winston, M.L. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola. Ecol.Appl. 15:871-881.

138. Morandini, Lora A., Winston, Mark L. 2007. Wild bee abundance and seed production in conventional, organic and genetically modified Canola. Ecological Applications1-11.

139. Muniappan, R. 2017. Climate change, agriculture and food security. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. The Anthropocene era has brought many advancements in science and technology but has also caused environmental damage, climate change, and biodiversity loss. All these exert an impact on agriculture, fisheries, and forestry. The earth has warmed up by 1.7 °C since 1880. Since, 1950, global warming has been caused by human releasing of greenhouse gases. In the long-run if emissions continue unchecked, it will cause the icecaps to melt resulting in a rise in sea level. This could cause collapse of agriculture. Asian monsoon will become less reliable and for billion of peoples who depend on monsoon for irrigation and livelihood, any disruption could be catastrophic.

140. Naeem, S., J. C. Ingram, A. Varga, et al. 2015. Get the science right when paying for nature's services. *Science* 347.6227: 1206-1207. This article pointed to the weakness of natural sciences in

the design and evaluation of payments for ecosystem services, and provided a suite of principles and guidelines for such programs to be successful from a natural-science perspective. Principles included ecological dynamics, baselines, inclusion of multiple services, monitoring, metrics, and ecological sustainability.

141. Naghski, J. 1951. No honey from tarrary buckwheat. Am.Bee J. 91:513-513.

142. Naidoo, R., and T. H. Ricketts. 2006. Mapping the economic costs and benefits of conservation. *PLoS Biology* 4.11: 2153-2164. The first comprehensive valuation of multiple ecosystem services in a conservation context, this article characterized the costs and benefits of conservation surrounding a protected area in the Atlantic forests of Paraguay. Ecosystem services included sustainable bush meat harvest, sustainable timber harvest, bio-prospecting, existence value, and carbon storage.

143. Nelson, E., G. Mendoza, J. Regetz, et al. 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Frontiers in Ecology and the Environment* 7.1: 4-11. The first application of the spatially explicit InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs). The case study in the Willamette Basin, Oregon, assessed tradeoffs between a suite of ecosystem services (carbon sequestration, soil conservation, water quality, and storm peak mitigation), biodiversity, and commodity production via stakeholder- defined scenarios.

144. Neupane, K.R. 2001. Foraging preference of honeybee species to selected horticultural crops. M.Sc. Thesis, submitted to IAAS, Rampur, Chitwan, Nepal.

145. Neupane, K. R. and R. B. Thapa. 2005. Pollen collection and brood production by honeybees (*Apis mellifera* L.) under Chitwan condition of Nepal**.** A study was carried out to investigate pollen foraging, storage and its impact on *Apis mellifera* L. brood production throughout the year under Terai condition of Nepal in 2003-2005. Number of pollen foragers, amount of pollen stored as beebread and brood in the colony differed significantly during different seasons. Number of pollen foragers (117.5 bees/ hive/ 5 min) and amount of pollen as beebread (2439.0 gm/hive) and number of brood (14787.2 brood cells/hive) were the highest during spring season, while the lowest number of pollen foragers (38.1 bees/ hive/5 min.) stored the lowest amount of beebread or pollen store (152.5 gm /hive) and produced the lowest number of brood (3811.7 brood cells/ hive) and bees in rainy season. Autumn, winter and summer seasons were normal for pollen collection and brood production, while starvation and nutritional deficiencies due to the acute shortage of pollen in rainy season was the major reason to decline or collapse the bee population before the honey flow season. Therefore, feeding bees with adequate amount of nutritionally rich pollen during rainy season is essential to maintain a healthy and strong bee colony for the production of higher honey and other hive products.

146. Neupane, K.R., D. D. Dhakal, R.B. Thapa and D.M. Gautam. 2006. Foraging performance of giant honeybees (*Apis dorsata* Fab.) to selected horticultural crops. J. Inst. Agric. Anim. Sci. 87-92. Foraging preference of giant honeybee, *Apis dorsata* Fab. to selected horticultural crops, litchi, *Litchi chinensis* Sonner, lemon, *Citrus limon* (Lin.) Burm. f., bottlebrush, *Callistemon citrinus* (Curtis) Skeels, cucumber, *Cucumis sativus* Lin., radish, *Raphanus sativus* Lin., and summer squash, *Cucurbita pepo* L., was studied during their blooming time at IAAS, Rampur, Chitwan, Nepal, 2001. The flowering of all six species of experimental plants started in the first week of March and lasted for two months with a peak flowering from 15 March to 5 April. Foraging preference of bees at 7.30, and 11.00 am and 3.00 pm and 5.30 pm during early, mid and late periods of flowering was assessed. Honeybees foraging at different times of day during early, mid and late flowering periods differed significantly. The highest mean number (8.04/min/m^2) of *A. dorsata* workers was recorded on bottle brush flowers at 7.30 am during early flowering period followed by litchi, summer squash and the lowest (0.25/min/m^2) on citrus at 5.30 pm during late flowering period. The bees never visited to the flowers of radish and cucumber. Pollen was preferentially collected from bottlebrush, summer squash and citrus in the morning and nectar from litchi and bottlebrush flowers throughout the day. Pollen foragers spent less time (2.9 sec/flower) and visited more flowers (17.96/min) when bees collected both pollen and nectar from the same plant. The number of outgoing and incoming foragers were the highest (59.0, 14, 44.0, 15/min/colony) at 7.30 am during mid flowering period and the lowest (17.6, 7, 17.0, 2/min/colony) at 5.30 pm during late flowering period, respectively.

147. Nicholls, C.I., and M.A. Altieri. 2012. Plant biodiversity enhances bees and other insect pollinators in agroecosystems. Agron Sustain Dev, A review. doi:10.1007/s13593-012-0092-y. Thirty-five percent of global production from crops including at least 800 cultivated plants depend on animal pollination. The transformation of agriculture in the past half-century has triggered a decline in bees and other insect pollinators. In North America, losses of bee colonies have accelerated since 2004, leaving the continent with fewer managed pollinators than at any time in the past 50 years. A number of factors linked to industrial modes of agriculture affect bee colonies and other pollinators around the world, ranging from habitat degradation due to monocultures with consequent declines in flowering plants and the use of damaging insecticides. Incentives should be offered to farmers to restore pollinator-friendly habitats, including flower provisioning within or around crop fields and elimination of use of insecticides by adopting agroecological production methods. Conventional farmers should be extremely cautious in the choice, timing, and application of insecticides and other chemicals. Here, we review the literature providing mounting evidence that the restoration of plant biodiversity within and around crop fields can improve habitat for domestic and wild bees as well as other insects and thus enhance pollination services in agroecosystems. Main findings are the following: (1) certain weed species within crop fields that

provide food resources and refuge should be maintained at tolerable levels within crop fields to aid in the survival of viable populations of pollinators. (2) Careful manipulation strategies need to be defined in order to avoid weed competition with crops and interference with certain cultural practices. Economic thresholds of weed populations, as well as factors affecting crop–weed balance within a crop season, need to be defined for specific cropping systems. (3) More research is warranted to advance knowledge on identifying beneficial weed species and ways to sponsor them to attract pollinators while not reducing yields through interference. (4) In areas of intensive farming, field margins, field edges and paths, headlands, fence-lines, rights of way, and nearby uncultivated patches of land are important refuges for many pollinators. (5) Maintenance and restoration of hedgerows and other vegetation features at field borders is therefore essential for harboring pollinators. (6) Appropriate management of non-cropped areas to encourage wild pollinators may prove to be a cost-effective means of maximizing crop yield.

148. Pagano, M.C. *et al*. 2016. Mycorrhizas in Agroecosystems. In: Pagano M. (eds) Recent Advances on Mycorrhizal Fungi. Fungal Biology. Springer, Cham. https://doi.org/10.1007/978-3-319-24355-9_8. The increasing consideration for more information to better understand agroecosystems and soils under different management has been recognized. The study of surface and deep soil responses to global change and how to enhance the resilience of soil ecosystems is thus urgently recommended. The examination and use of arbuscular mycorrhiza, which link the biotic and soil components providing ecosystem services for crops in the different associated soils, is reviewed. This chapter discusses advances in mycorrhizal fungi potential drawing on recent research worldwide. Studies on mycorrhizas have developed largely; however, the applications of mycorrhizas in agriculture and environmental issues are still incipient, and its limitations are also discussed.

149. Page, K., Y. Dang, and R. Dalal. 2013. Impacts of conservation tillage on soil quality, including soil-borne crop diseases, with a focus on semi-arid grain cropping systems. Australasian Plant Pathology, 42(3), 363–377. https://doi.org/10.1007/s13313-013-0198-y. Conservation tillage is a system of management that leaves at least 30 % of the soil surface covered by residue between crop harvests and planting, and may be combined with appropriate crop rotations to improve soil fertility and disease/weed management. This review examines the effect of conservation tillage on soil biological, chemical, and physical properties and how these interact to affect crop production. Improvements in physical attributes are widely observed under conservation tillage, and these improvements often lead to increased rates of water infiltration and storage. Increases in bulk density in the absence of cultivation, however, may lead to decreases in soil aeration. Conservation tillage may also lead to many soil chemical changes. Decreases in soil pH, changes to cation exchange capacity, and alterations to nutrient availability have all been observed. Changes to biological processes are generally characterised by increases in soil organic carbon (SOC) at or

near the surface of the soil profile, along with subsequent increases in soil microbial biomass and diversity. However, the presence of plant diseases and weeds may also increase under conservation tillage management. In semi-arid environments, the increases in soil water storage afforded by conservation tillage often lead to increased yield, especially in dry years. However, where crop disease and weed growth, a lack of plant available nutrients, and/or adverse soil structure limit plant development, lower yields may also be observed. Holistic systems that incorporate appropriate crop rotations, fertilizer and weed management are required to help control the negative aspects of conservation tillage, and ensure that improvements in soil quality lead to increases in crop production.

150. Partap, U. and T. Partap. 1997. Managed crop pollination: The missing dimension of mountain agricultural productivity. ICIMOD, Kathmandu, Nepal.

151. Partap, U. and T. Partap. 2002. Warning signal from the apple valley of the HKH: Productivity concerns and pollination problems. ICIMOD, Kathmandu, Nepal.

152. Partap, U., A.N. Shukla and L.R. Verma 2000. Comparative foraging behavior of *Apis cerana* and *Apis mellifera* in pollinating peach and plum flowers in Kathmandu valley, Nepal. *In:* M. Matsuka, L. R. Verma, S. Wongsiri, K. K. Shrestha and U. Pratap. (eds) Asian Bees and Beekeeping Progress of Research and Development. Oxford and IBH Pub. Co. Pvt. Ltd, New Delhi, India. pp. 193-197.

153. Partap, V. and Partap T. 2001. Declining Apple Production and Worried Himalayan Farmers: Promotion of Honeybees for Pollination. *Issues in Mountain Development*. ICIMOD. KTM. Nepal, Vol.-1.

154. Peterson, R. B., D. Russell, P. West, and J. P. Brosius. 2010. Seeing (and doing) conservation through cultural lenses. *Environmental Management* 45.1: 5-18. This paper critiqued the traditional ways of doing conservation. The authors asked for the inclusion of cultural lenses and anthropologists to conservation. They explained how local communities and local context shape conservation. The paper mostly criticized the permanent exclusion of social dimensions to conservation, and gave some insights on how these can be integrated.

155. Plieninger, T., S. Dijks, E. Oteros-Rozas, and C. Bieling. 2013. Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy* 33:118-129. A spatially explicit participatory mapping of cultural ecosystem services and several “dis-services” in Eastern Germany. Results reveal perceptions of bundles of services that vary according to respondents’ sociodemographic characteristics.

156. Pokhrel, S. 2006. Status and management of domesticated and wild honeybees (*Apis* spp.) in Chitwan, Nepal. Ph.D. Dissertation, TU, Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal.

157. Pokhrel, S., R.B. Thapa. F.P. Neupane and S. M. Shrestha. 2006. Absconding behaviors and management of *Apis cerana* Fab. Honeybee in Chitwan Nepal. J. Inst. Agric. Anim. Sci. 27:77-86. Twelve colonies of five-framed *Apis cerana* F. with about equal brood, hive storage and colony strength were prepared in November 2004 and the colony development parameters recorded. One-third of the colonies absconded in summer and about one-sixth in rainy season, while non-absconded colonies also slowed comb building, brood rearing, colony strength and hive storage in summer and rainy seasons. Feeding sugar candy and pollen substitute prevented absconding in May and July. Three weeks feeding in May resulted higher comb building (15.0%), higher brood rearing (158.8%), stronger colony strength (15.0%) and higher hive storage (171.2% honey, 270.9% pollen) in June. Those colonies having higher brood mite (*Varroa jacobsoni* Oud.) in winter absconded earlier.

158. Pokhrel, S., R.B. Thapa. F.P. Neupane and S.M. Shrestha. 2007. Feeding management of *Apis mellifera* Lin. Honeybee in relation to its supersedure in Chitwan, Nepal. IAAS. Res. Adv. 1: 99-113.

159. Power, A.G. 2010. Ecosystem services and agriculture: Tradeoffs and synergies. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2959–2971. https://doi.org/10.1098/rstb.2010.0143. Agricultural ecosystems provide humans with food, forage, bioenergy and pharmaceuticals and are essential to human wellbeing. These systems rely on ecosystem services provided by natural ecosystems, including pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. Preliminary assessments indicate that the value of these ecosystem services to agriculture is enormous and often underappreciated. Agroecosystems also produce a variety of ecosystem services, such as regulation of soil and water quality, carbon sequestration, support for biodiversity and cultural services. Depending on management practices, agriculture can also be the source of numerous disservices, including loss of wildlife habitat, nutrient runoff, sedimentation of waterways, greenhouse gas emissions, and pesticide poisoning of humans and non-target species. The tradeoffs that may occur between provisioning services and other ecosystem services and disservices should be evaluated in terms of spatial scale, temporal scale and reversibility. As more effective methods for valuing ecosystem services become available, the potential for 'win–win' scenarios increases. Under all scenarios, appropriate agricultural management practices are critical to realizing the benefits of ecosystem services and reducing disservices from agricultural activities.

160. Potschin, M., R. Haines-Young, R. Fish, and R. K. Turner. 2016. *Routledge handbook of ecosystem services*. London and New York: Taylor & Francis. A comprehensive reference text on ecosystem services including their biophysical characterization, economic valuation, and inclusion in decision making.

161. Pullaiah, T. (ed.). 2019. Global biodiversity V-1: Selected countries in Asia. Apple Academic Press Inc, Canada. The term 'biodiversity' came into common usage in the conservation community after the 1986 National Forum on BioDiversity, held in Washington, DC, and publication of selected papers from that event, titled Biodiversity, edited by Wilson (1988). Biodiversity is now the buzzword of everyone from parliamentarians to laymen, professors, and scientists to amateurs. There is a need to take stock on biodiversity of each nation. The present attempt is in this direction. The main aim of the book is to provide data on biodiversity of each nation. The ultimate aim of the book is for the conservation of biodiversity and its sustainable utilization.

162. Olsson, P., C. Folke, and F. Berkes. 2004. Adaptive co-management for building resilience in social-ecological systems. *Environmental Management* 34.1: 75-90. This paper presented examples from Sweden and Canada to show how local groups self-organized for ecosystem management and adapted to changing conditions. The authors recognized that adaptive co-management of ecosystems depended on each of the following: leaders with vision, enabling legislation to create social space for ecosystem management, capacity for monitoring environmental feedback, and combining various sources of knowledge. Adaptive co-management can be applied to the management of ecosystem services.

163. Rahman, K.A. 1940. Insect pollinators of toria (*Brassica napus* Linn. var. *dichotoma* Prain) and sarson (*Brassica campestris* Linn. var. *sarson* Prain) at Lyallpur. Indian J.Agric.Sci 10:422-447. Rahman L, Chan KY, Heenan DP (2007) Impact of tillage, stubble management and crop rotation on nematode populations in a long-term field experiment. Soil Tillage Res 95(1–2):110–119. doi:10.1016/j.still.2006.11.008. The population abundance of free-living and plant-parasitic nematodes was investigated in a long-term rotation/tillage/stubble management experiment at Wagga Wagga Agricultural Institute, New South Wales (NSW), Australia. The treatments were a combination of two crop rotations: wheat (*Triticum aestivum*)–wheat and wheat–lupin (*Lupinus angustifolius*); two tillage systems: conventional cultivation (CC) and direct drill (DD); and two stubble management practices: stubble retention (SR) and stubble burnt (SB). Plots of one of the wheat–wheat treatments received urea at 100 kg N ha^{-1} during the cropping season. Soil samples from 0–5 and 5–10 cm depths were collected in September (maximum tillering), October (flowering) and December (after harvest), 2001, to analyse nematode abundance. Soil collected in September was also analysed for concentrations of total and labile C, and pH levels. Three nematode trophic groups, namely bacteria-feeders (primarily Rhabditidae), omnivores (primarily

Dorylaimidae excluding plant-parasites and predators) and plant-parasites (*Pratylenchus* spp. and *Paratylenchus* spp.) were recorded in each soil sample. Of them, bacteria-feeders (53–99%, population range 933–2750 kg^{-1} soil) dominated in all soil samples. There was no difference in nematode abundance and community composition between the 0–5 cm and 5–10 cm layers of soil. The mean population of free-living and plant-parasitic nematodes varied significantly between the treatments in all sampling months. In most cases, total free-living nematode densities (Rhabditidae and Dorylaimidae) were significantly ($P < 0.001$) greater in wheat–lupin rotation than the wheat–wheat rotation irrespective of tillage and stubble management practices. In contrast, a greater population of plant-parasitic nematodes was recorded from plots with wheat–wheat than the wheat–lupin rotation. For treatments with wheat–wheat, total plant-parasitic nematode (*Pratylenchus* spp. and *Paratylenchus* spp.) densities were greater in plots without N-fertiliser (295–741 kg^{-1} soil) than the plots with N-fertiliser (14–158 kg^{-1} soil). Tillage practices had significant ($P < 0.05$) effects mostly on the population densities of plant-parasitic nematodes while stubble management had significant effects ($P < 0.05$) on free-living nematodes. However, interaction effects of tillage and stubble were significant ($P < 0.01$) for the population densities of free-living nematodes only. Population of Rhabditidae was significantly higher in conventional cultivated plots (7244 kg^{-1} soil) than the direct drilled (3981 kg^{-1} soil) plots under stubble retention. In contrast, plots with direct drill and stubble burnt had significantly higher populations of Dorylaimidae than the conventional cultivation with similar stubble management practice. No correlations between abundance of free-living nematodes, and concentration of total C and labile C in soil were observed in this study. These results showed that stubble retention contributed for enormous population density of free-living (beneficial) nematodes while conventional cultivation, irrespective of stubble management, contributed for suppressing plant-parasitic nematodes.

164. Rasmussen, P.E., and C.R. Rohde. 1988. Long-term tillage and nitro-gen fertilization effects on organic nitrogen and carbon in a semiarid soil. Soil Sci. Soc. Am. J. 52:1114–1117. https://doi.org/10.2136/sssaj1988.036159950052 00040041x. Maintaining or improving soil organic matter has high priority in agriculture because of its beneficial effect on soil physical, chemical, and biological properties. Soil organic N and C were measured 44 yr after establishment of a long-term experiment to evaluate tillage and fertilizer effects in a winter wheat (*Triticum aestivum* L.)-fallow rotation on a coarse-silty mixed mesic Typic Haploxeroll. Main treatments consisted of three primary tillage systems, one conventional (moldboard plow) and two stubble mulch (offset disc, subsurface sweeps). Subplots consisted of six N treatments, 493, 728, 986, 1221, 1714, and 2207 kg N ha^{-1} applied over 44 yr. Organic N and C in the top 75 mm of soil were 26 and 32% higher, respectively, in the two stubble mulch systems than in conventional tillage, and equal below 75 mm. Stubble mulch plots contained 245 kg more N ha^{-1} than conventionally tilled plots, representing the conservation of 5.7 kg N ha^{-1} yr^{-1}. Nitrogen fertilization increased soil

N linearly in all tillage treatments, with 18% of the applied N incorporated into the soil organic fraction. Applied N also increased soil C linearly on plots with previous S application. Soil C was higher on plots with no previous S than on comparable plots with previous S, however, which suggests an S deficiency that altered S, but not N, transformations in soil. Identical N fertilization effects on soil organic N and C in both stubble mulch and conventional tillage suggests that N transformations were the same in both systems,

165. Ribeiro, G.S., E.M. and A. C. Cald. 2017. Biology of pollination of *Citrus sinensis* variety 'Pera Rio.' Rev Bras Frutic 39:. https://doi.org/10.1590/0100-29452017033. Aspects related to the floral biology of *Citrus sinensis* 'Pera Rio' variety were studied in the present work aiming to obtain information about the pollination ecology in the local agriculture. Studies of flowering, anthesis, pollen / ovule ratio, stigmatic receptivity, pollen viability, nectar characterization and floral visitors were carried out. From the data studied, the following information was obtained: C. sinensis variety 'Pera Rio' flourishes in two annual periods (dry and rainy), the anthesis occurs from 9:00 AM with duration of 24 hours, during which period stigma receptivity, pollen viability and nectar secretion are highly significant, demonstrating that the species also possesses characteristics of allogenic plants. *Apis mellifera* was a floral visitor, with a greater number of individuals with a Relative Frequency (RF) of 51.1%. Melipona scutellaris obtained second place in visits with RR = 23.6%; Followed by *Trigona spinipes* with FR = 17.7%. The two seasons (dry and rainy) presented high similarity (Morisita index = 0.64). *C. sinensis* has floral biology favorable to cross pollination and bees *A. mellifera* and *M. scutellaris* are potential pollinators of this fruit in the conditions in the region of the Recôncavo Baiano. The reproductive system of *C. sinensis* is mixed, being favorable to entomophilic pollination.

166. Rijal, S. and R.B. Thapa. 2017. Assessment of pollination deficit in rapeseed (Brassica campestris L. var. toria) and its impact on yield in different agro-ecosystems of Chitwan, Nepal. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. Crop pollination is crucial for increasing yield, ensuring food security, improving livelihoods of farmers and pollinators' conservation as well. The pollination treatments in rapeseed were: i) open pollination; ii) plants caged with honeybees (*Apis mellifera* L.); iii) hand pollination; and iv) control (plots caged without pollinators) replicated four times. Then pollinators visiting flowers, plant growth, and yield were recorded. There was different levels of pollinators in semi-natural, organic and intensive agriculture sites, however deficit in pollination noticed in intensive agriculture field resulting in lower yield. The dominant pollinators were: Hymenopterans, mostly honeybees (*Apis mellifera* L., *Apis cerana* F., *Apis dorsata* F. and *Apis florea* F.) including other pollinators like Syrphid flies, *Syurphus* sp., *Eristalis* sp. as dominant dipteran pollinators and some other Coleopteran and Lepidopteran pollinators, respectively.

167. Rodrigo Martínez-Sastre, Daniel García, Marcos Miñarro and Berta Martín-López. 2020. Farmers' perceptions and knowledge of natural enemies as providers of biological control in cider apple orchards, Journal of Environmental Management, 266, (110589). https://doi.org/10.1016/j.jenvman.2020.110589. While the importance of biological control for crop production is widely acknowledged, research on how farmers perceive on-farm natural enemies remains scarce. This paper examines cider-apple farmers' perceptions and knowledge of the concept of biological control and the specific organisms underpinning its provision (i.e. natural enemies) in the cider-apple orchards of Asturias (N Spain). Although these orchards host a high diversity of natural enemies, certain pests continue to be a problem, e.g. the codling moth and the fossorial water vole. By conducting 90 face-to-face surveys, we found that farmers "under-estimated" the importance of biological control and the role played by natural enemies in suppressing pests from cider-apple orchards. Furthermore, farmers were particularly unaware of the indirect benefits of biological control, such as the increased quality and yield of product. Farmers also perceived that different taxa of natural enemies contribute to biological control to differing extents, for example, birds, such as buzzard, robin and tit, were perceived as the most important natural enemies, while arachnids and insects (excluding ladybug) were perceived as less important. This perceived difference in the biological control contribution of vertebrates and invertebrates could be influenced by farmers' local knowledge, acquired on-farm through daily experiences, as well as from external sources. In addition, we found that farmers did recognize many interactions between natural enemies and pests, although there were serious misconceptions and knowledge gaps. Finally, we revealed that education level, being a full-or part time farmer rather than a 'hobby' farmer, time spent working in agriculture, and orchard size are all factors that positively influence farmer's perception of natural enemies. Our results provide insights for a future management of cider-apple orchards which promotes biological control through: (1) creating initiatives to develop farmers' knowledge regarding biological control and natural enemies, (2) fostering traditional farming systems that contribute to preserving local ecological knowledge of biological control, and (3) establishing networks of farmers so they can learn from each other and share local knowledge.

168. Roe, D., N. Seddon, and J. Elliott. 2019. Biodiversity loss is a development issue a rapid review of evidence. International Institute for Environment and Development, London, UK. From genes to micro-organisms to top predators and even whole ecosystems, we depend on biodiversity for everything from clean air and water to medicines and secure food supplies. Yet human activities are destroying biodiversity around 1000 times faster than natural 'background' rates. This global biodiversity crisis is hitting the poorest communities first and hardest, because they can ill-afford to 'buy in' biodiversity's previously-free goods and services (and are already bearing the brunt of climate change). So why does the development community often ignore biodiversity loss? This

paper unpicks misunderstandings and sets out the evidence that biodiversity loss is much more than an environmental problem – it is an urgent development challenge.

169. Rode, J., E. Gómez-Baggethun, and T. Krause. 2015. Motivation crowding by economic incentives in conservation policy: A review of the empirical evidence. *Ecological Economics* 117:270-282. A comprehensive review of the empirical evidence for the theory of motivational crowding out, by which the addition of monetary incentives undermine existing motivations for conservation. The authors found evidence of "crowding out" and, to a lesser extent, of "crowding in".

170. Rosa García, R,, and M. Miñarro. 2014. Role of floral resources in the conservation of pollinator communities in cider-apple orchards. Agric. Ecosys. Environ. 183:118–126. doi:10.1016/j.agee. 2013.10.017. Pollinators are generally assumed to be in decline but a proper habitat management could help to conserve pollination services. In 2012 we surveyed the groundcover in nine cider-apple orchards to (I) identify the floral and faunal communities present in the ground floor, (II) assess the attractiveness of the local spontaneous flowers to insects and (III) determine the role that the flower community may play for the conservation of the associated arthropods in general and of pollinators in particular. The apple orchards provided a continuous succession of floral resources in the groundcover with differences among orchards in the abundance, richness and diversity of flowers. Flowering plant species were visited by a wide variety of insects, mostly from the orders Hymenoptera (70%) and Diptera (25%). Wild bees accounted for 27% of hymenopterans and hoverflies for 30% of dipterans. Flowering plants differed in the number of taxa they attracted and in their attractiveness for particular insect groups and for insects as a whole. A total of 16,159 arthropods were collected from the groundcover, and 2064 individuals belonged to taxa involved in the pollination. Pollinators and arthropods (exemplified by hemipterans and coleopterans) differed between orchards and periods and were affected by the plant community. Plant species richness and the abundance of some plant species favored the presence of both pollinators and arthropod assemblages while flower abundance had only a marginal effect on those communities. Pollinators were also affected by plant diversity. Among-orchard differences in the plant community suggest that management recommendations must be site-specific to ensure the permanent availability of diverse floral resources for the arthropod community and for pollinators in particular. Therefore, a proper groundcover management could provide benefits for apple growers by improving pollination services.

171. Roubik, D.W. (ed.). 2014. Pollinator safety in agriculture. FAO, Rome, Italy. A careful look at pollinators can help us understand how they may live and carry out their vital function in our world, and how we can manage not to destroy or poison much of it ourselves. Honeybees have extraordinary capacities of flight, homebuilding, and food seeking, as well as many defenses from natural enemies. In the brain of a bee there is a map of the environment, and a sharp memory of

where food and stress sources exist. The complex dynamics of many things are learned by bees. They make a living by making the right choices, permitted by gathering the correct information. Our struggle to understand and maintain our own environment in a healthy state closely matches the bee's instinctive pursuit. The greening of pollination is our goal. That is, native or wild pollinators can be sustained, while those sought and utilized in agriculture can benefit from the same practices and insights. Our human environment will also become safer, as our crops receive the benefits that only the pollinating animals can bring them. This book, keyed to practitioners in the tropical world, testifies that we can positively alter the way food is produced by managing agriculture to avoid known exposure risks of pollinators to pesticides. GEF/UNEP-supported project on the "Conservation and Management of Pollinators for Sustainable Agriculture, through an Ecosystem Approach", FAO and its partners in seven countries have been developing tools and guidance for conserving and managing pollination services to agriculture.

172. Rowen EK, Tooker JF, Blubaugh C. 2019. Managing fertility with animal waste to promote arthropod pest suppression. Biol. Control 134:130–40. https://doi.org/10.1016/j.biocontrol.2019.04.012. Fertility management is key to maintaining soil quality in crop systems and can have important implications for plant growth and insect pest populations. Organic fertility amendments, particularly animal manures, are hypothesized to simultaneously promote plant vigor, herbivore resistance, and top-down pest suppression. Animal-waste fertilizers influence pest control in at least two ways: first, they can affect prey suppression from the bottom up by changing macro- and micronutrient concentrations in the plant, shaping the rhizosphere community, elevating production of defensive chemicals and altering herbivore-induced plant volatiles (HIPVs). Second, animal-waste fertilizers can affect conservation biological control from the top down by improving the soil-surface habitat for predators through altered soil tilth, organic matter, water retention, and by supporting decomposers communities that also feed soil-dwelling predators as non-pest prey. However, while animal-waste fertilizers may enhance pest suppression when applied correctly, when manure is overused there are also costs of excess fertility pest management and water quality. In this review of the existing body of research on interactions between animal-waste fertilizers, herbivores, and natural enemies, we summarize trends, report costs and benefits, and identify research opportunities for future studies.

173. Ruhl, J. B., and J. Salzman. 2007. The law and policy beginnings of ecosystem services. *Journal of Land Use & Environmental Law* 22.2: 157-172. This article is a review on the development of ecosystem services as it grew from a concept to become a central way of understanding and doing conservation. It also discussed the roles of national governments and international organizations in the policies that protect ecosystem services.

174. Sahu, R.C., R.B. Thapa, C.K. Mandal, S.M. Shrestha and M. Sapkota. 2007. Effect of Endosulphan on the mortality of forager honeybees (*Apis mellifera* L. and *Apis cerana*). IAAS. Res. Adv.1: 147-150.

175. Sahu, R.C., R.B. Thapa, C.K. Mandal, S.M. Shrestha and M. Sapkota. 2007. Performance of *Apis mellifera* L. in thermocol hive during spring and summer season in Chitwan, Nepal. IAAS. Res. Adv.1: 151-154.

176. Sapkota, S., R.B. Thapa, R. Regmi, N. Krakuer, A. Jha, N. R. devkota, P. K. jha and P. Thapa. 2017. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. Recent studies have proven that healthy levels of biodiversity and functional diversity promote sustainable ecosystem functioning. Similarly, in agro-ecosystem high levels of biodiversity are expected to maintain ecosystem services. In this respects dung beetles are of considerable ecological and economical importance because of their role in decomposition of animal excrement, the cycling of nutrient and the resulting enhancement in the productivity of grassland ecosystem.

177. Satterfield, T., R. Gregory, S. Klain, M. Roberts, and K. M. A. Chan. 2013. Culture, intangibles and metrics in environmental management. *Journal of Environmental Management* 117:103-114. This article addresses the difficult but necessary collaboration of researchers of culture in the valuation of ecosystem services and environmental management. The authors propose and describe a suite of alternative methodologies for valuation in quantitative-qualitative terms, borrowing from risk assessment.

178. Sandhu, H.S., S.D. Wratten, and R. Cullen. 2007. From poachers to gamekeepers: Perceptions of farmers towards ecosystem services on arable farmland. International Journal of Agricultural Sustainability, 5(1), 39–50. https://doi.org/10.1080/14735903.2007.9684812. Management of ecosystem services (ES) is vital to maintain and improve the productivity of agricultural systems in order to meet the food demands of a growing human population. However, some land management practices can severely reduce the ecological and financial contribution of some of these services to agriculture, which in the longer term can offset the ability of farming to produce large amounts of food and fibre. Therefore, to improve the understanding and enhancement of these services, it is crucial to know the opinions of farmers who manage ES on their land. Being in close contact with the land provides them with an opportunity to understand its natural processes and functions as well as to act as its stewards. This paper describes ES associated with arable farming in Canterbury, New Zealand and analyses the results of a survey of farmers' perceptions of these services. There was no difference between the measured perceptions of these services by organic and conventional farmers except in the case of biological control. However, organic farmers gave a higher score to 16 individual services compared with conventional farmers. Also,

for organic farmers, the importance of some of these services increased significantly with the number of years the farmers had been operating under an organic regime.

179. Sayer, J., T. Sunderland, J. Ghazoul, J.L. Pfund, D. Sheil, E. Meijaard, and L.E. Buck. 2013. Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. Proceedings of the National Academy of Sciences of the United States of America, 110(21), 8349–8356. https://doi.org/10.1073/pnas.1210595110. "Landscape approaches" seek to provide tools and concepts for allocating and managing land to achieve social, economic, and environmental objectives in areas where agriculture, mining, and other productive land uses compete with environmental and biodiversity goals. Here we synthesize the current consensus on landscape approaches. This is based on published literature and a consensus-building process to define good practice and is validated by a survey of practitioners. We find the landscape approach has been refined in response to increasing societal concerns about environment and development tradeoffs. Notably, there has been a shift from conservation-orientated perspectives toward increasing integration of poverty alleviation goals. We provide 10 summary principles to support implementation of a landscape approach as it is currently interpreted. These principles emphasize adaptive management, stakeholder involvement, and multiple objectives. Various constraints are recognized, with institutional and governance concerns identified as the most severe obstacles to implementation. We discuss how these principles differ from more traditional sectoral and project-based approaches. Although no panacea, we see few alternatives that are likely to address landscape challenges more effectively than an approach circumscribed by the principles outlined here.

180. Scherr, S.J., and J.A. McNeely. 2008. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'eco-agriculture' landscapes. Philosopy Transaction R Society London B Biological Science, 363(1491), 477–494. https://doi.org/10.1098/rstb.2007.2165. The dominant late twentieth century model of land use segregated agricultural production from areas managed for biodiversity conservation. This module is no longer adequate in much of the world. The Millennium Ecosystem Assessment confirmed that agriculture has dramatically increased its ecological footprint. Rural communities depend on key components of biodiversity and ecosystem services that are found in non-domestic habitats. Fortunately, agricultural landscapes can be designed and managed to host wild biodiversity of many types, with neutral or even positive effects on agricultural production and livelihoods. Innovative practitioners, scientists and indigenous land managers are adapting, designing and managing diverse types of 'eco-agriculture' landscapes to generate positive co-benefits for production, biodiversity and local people. We assess the potentials and limitations for successful conservation of biodiversity in productive agricultural landscapes, the feasibility of making such approaches financially viable, and the organizational, governance and policy frameworks needed to enable eco-agriculture planning and implementation

at a globally significant scale. We conclude that effectively conserving wild biodiversity in agricultural landscapes will require increased research, policy coordination and strategic support to agricultural communities and conservationists.

181. Shrestha, J.B. and B.N. Singh 1996. The training manual of beekeeping. Published by Non-formal Education Kathmandu, Nepal. The training manual of beekeeping depicts the full explanation about the principles and practices of beekeeping in Nepal with adequate guidance of practical exercises for the grass-root level beekeepers.

182. Shrestha, J.B. 2006. Beekeeping. In: Dahal, D. (ed) Nepal Agriculture Technology Book. Agriculture Information and Communication Centre. Ministry of Agriculture and Cooperatives, Government of Nepal (GON). Pp 216-220. The book on agriculture technology including beekeeping depicts the full explanation about the principles and practices of agricultural technology in Nepal with adequate guidance for the grass-root level farmers and beekeepers.

183. Shrestha, J.B. 2001. Investigation of the parasitic mites; Tropilaelaps clareae Delfinado and Baker, and their host Apis dorsata Fabricius in Chitwan, Nepal. **Thesis, M.Sc. Agriculture (Plant Protection).** Institute of Agriculture and Animal Science, Rampur, Chitwan, Tribhuvan University, Napal. 79 pp. The study was carried out to find out the mites attacking Apis dorsata Fabricius, their rate of infestation and intensity (the number of mites per cell infested), and the trend of A. dorsata colony migration in Chitwan district. Samples of deserted combs of the last and the current seasons, those of live bees and brood were collected three times (at one and half month's interval) from five sites and examined under microscope for mite infestation. Monthly observations on the arrival and departure of A. dorsata colonies at eight sites were also taken throughout the year. The mite found in brood cells and adult bees (A. dorsata) was only Tropilaelaps clareae Delfinado and Baker whereas, Forcellinia galleriella Womersley was also found in deserted comb samples. The overall (general) mean (± SE) rate of brood cell infestation by T. clareae was 7.24 (± 0.66) %. The mean (± SE) number of T. clareae per 100 brood cells was 16.67 (± 2.04) and the mean (± SE) number of T. clareae per 100 adult bees was 0.51 (± 0.06). The overall mean (± SE) parasitic intensity (number of T. clareae per unit cell infested) was 1.98 (± 0.13). Almost all of the above variables increased steadily but significantly over sampling times (mid-December 2000, January-end 2001 and mid-March 2001). The mean (± SE) percent cells infested by T. clareae in deserted combs was 3.0 (± 0.38) % and the mean (± SE) number of T. clareae per 100 cells was 4.05 (± 0.53). The mean (± SE) parasitic intensity was 1.41 (± 0.10). Similarly, the mean (± SE) number of F. galleriella per 100 cells in deserted combs was 55.38 (± 4.38). The mean (± SE) survival (hours) of T. clareae in vials at room temperatures (21° – 30° C) was 8.12 (± 0.58) hours. The mean number of colonies declined steadily from May to August (2000), no colony in September and October (2000), got the highest peak in January (2001), and started again declining from March (2001) onward. The annual mean (± SE) number of A. dorsata

colonies was 6.07 (± 0.74). The monthly mean number of colonies was negatively correlated with the monthly mean temperature, and significantly affected by both 'Time' and 'Sites'. It reveals that A. dorsata needs conservation for bio-diversity maintenance.

184. Shrestha, J.B. 1993. Comparing pollen foraging strategy of honey bee (Apis mellifera L.) colonies. **Thesis, Diploma in Apiculture (Post-graduate).** College of Cardiff, University of Wales, U.K. 89 pp. It was intended to compare and contrast the pollen foraging strategy of the honeybee colonies (Apis mellifera L) by analyzing pollen load samples trapped from their hives. Two colonies of approximately equal strength were moved to the site (Berry Hill Farm, Castleton, Cardiff, UK) and pollen traps were attached to the entrance of the hives, before honeybees were released at the new site. Pollen load samples trapped from both colonies were daily collected at 2.00 pm and 7.30 pm. There was no pollen collected in the morning by honeybee colonies until 10.00 am. Each collected samples of pollen load were individually separately homogenized and two slides from each sample were prepared for microscopical examination. The first colony collected 20 species of pollen over the whole duration of study (from 6th May to 14th May, 1993), and among them 19 species were similar. The species occupying three highest mean percentages of pollen in samples trapped from the first colony were Malus species (43.26 %), Crataegus monogyna (16.7 %) and Prunus / Pyrus (9.85 %), and those in the samples trapped from the second were Malus species (27.22 %), Fragaria x ananassa (19.4 %) and Acer pseudoplatanus (13.87 %). While comparing two commercially important fruit crops it was revealed that the first colony had preference for Malus species whereas the second colony had preference for Fragaria x ananassa (Table 14.1-14). The first colony gathered up to 6.43 times as much Malus species pollen as the second colony did (Table 14.1). Conversely, the second colony collected up to 57.83 times as much Fragaria x ananassa pollen as the first colony did. There was no significant difference between weights of samples collected by both colonies.

185. Shrestha, J.B. 2007. World Trade Organization (WTO) and Its Implications on Nepalese **Apiculture** In: Agricultural Development Journal, Vol. 4 (2063/64). June 6, 2007. GON, Nepal. Pp 20. Having been a member of WTO Nepal needs to abide by WTO agreements, especially the Agreement on the application of sanitary and phyto-sanitary measures (SPS) and the Agreement on Technical Barriers to Trade (TBT).This has some crucial and challenging implications on Nepalese apiculture. Nepal became deprived of the opportunity to export honey to European Union (EU) countries, as Nepal had to have a **residue-monitoring plan**, approved by the EU, conforming to the regional norms such as Council Directive 96/23/EC of 29 April 1996. The infrastructures (including laboratory facilities from central to local levels with competent human resources) must be developed with a categorical mandate and authorities for quality control of the products, their standardization, and their marketing system with appropriate facilities for the monitoring, validation and certification system for food safety, hygiene, production and processing standard.

It entails that building and strengthening domestic capacity of different key stakeholders be realized including public institutions, the bureaucracy, private sector, civil society, and academic institutions and focusing in the development of human resource increasing core competencies and promoting specialization in the most crucial areas. Nepal must develop the range of exports, both goods and services and enhance capacity to be able use system tools to realize potential opportunities available in WTO to protect domestic industries and apicultural entrepreneurship as well as to sustain meeting challenges emerging in the WTO regime. By dint of acquiring the WTO membership, Nepal has a claim for equal rights in the international trading system. It necessitates that building supply side be focused and a smooth trading mechanism be put in place, activating the trade monitoring authority, modernizing customs administration and simplifying customs operations. WTO membership has also opened up opportunities of markets of the rest of the member states for Nepalese exports - both goods and services.

186. Shrestha, J.B. 2006. Integrated pest management (IPM) and organic honey. In: Proceedings of the seminar organized by Plant Protection Society Nepal-2003, Harihar Bhawan, Lalitpur on 25-27 August 2006 (2063/5/9-11). Integrated Pest Management (IPM) is an applied ecology approach to provide the means of protecting and improving human, animal, and plant health in a way that is sensitive to the environment and to sustaining natural resources. IPM is the selection, integration, and implementation of control as determined by anticipated economic, ecological, and sociological consequences. IPM is a sustainable approach to managing pests (insects, diseases, weeds, etc.) by combining tools such as biological, cultural, physical and chemical in a way that minimizes economic, health and environmental risks. IPM is not biological control, although biological control is a useful tactic. IPM is not an organic program although we may integrate organic materials into our control tactic. Nor is IPM anti-pesticidal, but generally it attempts to reduce chemical dependency with a mix of control tactics. IPM allows beekeepers to adopt a more balanced approach to mite and disease control that is safer for the beekeeper, bees, hive products and the environment. The hives should consist of natural materials presenting no risk of contamination to the environment or the bee products. The treatment and management of hives should respect all the principles of organic animal husbandry contained in International Standards. The health of bees should be based on prevention of disease, using techniques such as adequate selection of breeds, favorable environment, balanced diet and appropriate husbandry practices. The sources of natural nectar, honeydew and pollen should consist essentially of organically produced plants and/or naturally occurring (wild) vegetation. IPM-FFS and /or organic farming should be highly promoted in order to reduce or minimize the application of pesticides, solve various technological problems for producing high quality honey or other bee products and their processing.

187. Shrestha, J.B. 2006. Combating desertification with sericulture and apiculture In: The Journal of Agriculture and Environment. Gender Equity and Environment Division. Ministry of Agriculture and Cooperatives, GON, Nepal. Pp 6-13. Desertification is an accumulative outcome of unsustainable land use practices along with deforestation, inappropriate farming practices, intensive agriculture, overgrazing, landslides and floods, and shifting cultivation. These factors destabilize ecosystems, accelerate silting of reservoirs and other water bodies, and change hydrological regime resulting in land degradation process. Sericulture has a positive impact on the environment, since it encourages the plantation of mulberry plants, and increases vegetation and green land, which in turn bring about the positive effect towards preventing or reversing desertification. As roots of mulberry plants are very profuse and robust, they are very helpful in holding soil firmly and preventing soil erosion. Honeybees and beekeeping combat desertification through pollination of valuable plant species, which contribute to soil conservation, control erosion, and provide valuable resources for wildlife. Through beekeeping, communities are empowered to utilize the natural resources that are in their environment and they learn how to manage, take care of and earn money through utilizing the resources. It is a valuable conservation tool, instigating people to derive economic benefit not only from indigenous forests but also from other floral resources in a non-destructive way, ensuring local participation in conservation efforts.

188. Shrestha, J.B. 2006. Honey quality and trade opportunities in the context of World Trade Organization (WTO). In: Proceedings of the seminar organized by Plant Protection Society Nepal-2003, Harihar Bhawan, Lalitpur on May 10, 2005 (Baisakha 27, 2062). Honey produced in Nepal is of high quality, however, the monitoring, validation and certification system is weak, and the food safety, hygiene, production and processing standard are also not guaranteed. For these purposes, the infrastructures (including laboratory facilities from central to local levels with competent human power) must be developed with clear-cut mandate and authorities for quality control of the products, their standardization and their marketing system with appropriate facilities. Broadly speaking, to sustain in the WTO regime, Nepal faces two major challenges viz. it must develop the range of exports, both goods and services and enhance capacity to use tools available in WTO to protect local industries and agricultural entrepreneurship. WTO membership has ensured equal rights to Nepal in the international trading system. It entails that building supply side be focused and a smooth trading mechanism be put in place, activating the trade monitoring authority, modernizing customs administration and simplifying customs operations. WTO membership has also opened up opportunities of markets of at least 147 countries for Nepalese exports- both goods and services. Shrestha, J.B. (2005) Keeping bees in cities. In: The Journal of Agriculture and Environment. Published by Ministry of Agriculture and Cooperatives, HMG, Nepal. In the context of monotonous and hectic lifestyle of city-dwellers, urban beekeeping can prove to be a relieving hobby in addition to the income generation and nutritional supplement

through bee products. Beekeeping is a noble occupation that is within the capabilities of nearly anyone and that can be started with very little capital and place to get benefits from it. Through beekeeping, communities are empowered to utilize the natural resources that are in their environment and they learn how to manage, take care of and make money from the resources in their own environment. It is a valuable conservation tool, instigating people to derive economic benefit not only from indigenous forests but also from other floral resources in a non-destructive way, ensuring local participation in conservation efforts. It also makes a very significant contribution to other forms of agriculture by effecting or accomplishing the pollination of many economically important plants. Bees produce other products that can be harvested and put to good use, including beeswax, propolis, royal jelly, and bee venom. Even the pollen they bring back to the hive can be harvested, which is rich in protein and makes a healthy food supplement in diets.

189. Shrestha, J.B. 2004. Honeybees and environment. In: The Journal of Agriculture and Environment. Published by Ministry of Agriculture and Cooperatives, HMG, Nepal. The main significance of honeybees and beekeeping is pollination of plant species, which contribute to soil conservation, control erosion, and provide valuable resources for wildlife. Basically, flowers provide nectar and pollen for bees and bees provide cross-pollination for plants -- a kind of inter-dependence resulting in various co-evolutions. The natural environment is required to provide bees and plants with habitat or nesting sites. As a result of cross-pollination by bees, somatic, reproductive and adaptive heterosis or hybrid effects occur in plant progeny, either in a single way or in different combinations bringing about significant qualitative and quantitative changes in the economic and biological characters of plants. Honeybees often facilitate genetic enrichment of native plants through cross-pollination activities for adaptation of plants to the changing environment and for the development of new varieties. Development and promotion of agro-forestry can improve, provide or reconstruct pollinators' habitats and provide forage resources contributing greatly to the conservation and protection of pollinators and hence to sustainable agricultural development. Organic farming or integrated pest management programs should be highly promoted in order to minimize the use of pesticides.

190. Shrestha, J.B. and T.B. Thapa. 2004. The context of the WTO Agreements on Sanitary and Phytosanitary (SPS) Measures and Technical Barriers to Trade (TBT) and Nepal. South Asia Watch on Trade, Economics and Environment (SAWTEE) Briefing Paper. To take benefits from the WTO Agreements Nepal must play a proactive role especially on the part of Agreement on Sanitary and Phyto-sanitary Measures, SPS) and Agreement on Technical Barriers to Trade, TBT, which are important agreements pertinent to WTO. Being one of the least developed countries, Nepal should be able to capture the opportunities and facilities provisioned in Special and Differential Treatment of the WTO. Nepal must be very efficient and capable of achieving the desired result with the minimum use of resources, time, and effort.

191. Shrestha, J.B. 2003. The World Trade Organization (WTO) Agreement on Sanitary and Phytosanitary Measures and farmers' rights in Nepal. Paper presented in 'National Workshop on Protecting farmers' Rights for Food Security and Sustainable Livelihood' organized by National Alliance for Food Security - Nepal (NAFOS) and USC-Nepal. 06 07 August 2003, Dhulikhel. Agreement on Sanitary and Phytosanitary Measures (SPS) is one of the important agreements of WTO and it brings about both opportunities and challenges for the protection of health of human beings, animals and plants in Nepal. It also provides with the opportunities for getting justice against the unjust and discriminatory behavior against the least developed countries like Nepal. There are no separate laws or acts concerning farmers' rights in Nepal, although they are needed as soon as practicable. However, they have been mentioned in short in various acts. Nepal needs its own sui generic for biodiversity conservation and protection of its traditional technologies, resources and innovations.

192. Shrestha, J.B. and K.K. Shrestha. 2000. Beekeeping in Nepal: Problems and potentials. In: Fourth Asian Apicultural Association International Conference Kathmandu, Nepal, March 23-28, 1998. Asian bees and beekeeping, progress of research and development: proceedings edited by M. Matsuka, L.R. Verma, S. Wongsiri, K. K. Shrestha, and U. Partap. New Delhi, Oxford and IBH Publishing Co. Pvt. Ltd. Pp 262-265. In Nepal, bee-keeping with *Apis cerana* F. is taken up by rural farmers as a traditional household integral part of agricultural activities. They keep bees in hollow logs and/or wall cavities. Top bar log hives or even frame hives can be seen in some of trained beekeepers. Seasonal management or routine inspection of hives is only practiced by some trained bee-keepers in top bar or frame hives. The beekeepers of Nepal face two dearth periods in the mid hills rich in beekeeping. Migration of colonies is not practiced. Bee-keeping with *Apis cerana* F. has various problems such as absconding, higher swarming tendency, frequent absence of queen, frequent fighting and robbing, susceptibility to diseases and pests, low honey yields. Deforestation and environmental degradation, the use of pesticides, bee-equipment standardization, applied research, training programs with follow-ups need further attention. Nepal is very rich in various bee species and bee flora having a great potential for their improvement. Training trainers and in turn farmers to use the available technology, selection and multiplication of colonies having better traits, promotion of managed bee pollination through zonations can make *Apis cerana* F. bee-keeping a sustainable income generating activity at the door steps of the rural poor. The potentiality and the stimulus in beekeeping deserves the international support for further work in *Apis cerana* F. beekeeping with a larger goal of alleviating poverty and helping food security in the region.

193. Shrestha, J.B. 1989. Traditional beekeeping in Nepal and its prospects. In: Proceedings of 1st Asia-pacific conference on Entomology, Chiangmai, Thailand, November 17-23, 1989. Nepal is blessed with wide range of natural resources including vegetation providing with an ideal

environment for the development of beekeeping. In Nepal, Traditional beekeeping has been an important heritage since time immemorial. There is tremendous scope for developing beekeeping in Nepal. Deforestation and environmental degradation need greater attention not only for the betterment of beekeeping but also for overall sustainable development in the country. Joint but coordinated effort of all stakeholders must be directed towards flourishing beekeeping with proper impetus for the optimum utilization of full potential of the boon of the natural resources in Nepal.

194. Simon, S., J. Bouvier, J. Debras, and B. Sauphanor. 2010. Biodiversity and pest management in orchard systems. A review. Agron Sustain Dev 30:139–152. doi:10.1051/agro/2009013. Conventional agriculture is based on a high level of chemical inputs such as pesticides and fertilizers, leading to serious environmental impacts, health risks and loss of biodiversity in agro-systems. The reduction of pesticide use is a priority for intensively sprayed agricultural systems such as orchards. The preservation and promotion of biodiversity within orchards and their boundaries is therefore an issue to explore. Indeed, orchard systems contain high plant diversity and perennial multi-strata designs that provide wealthy resources and habitats to living communities such as beneficial organisms. Orchards thus offer favorable areas to maintain food-webs within the agro-system, provided that favorable situations are not altered by cultural practices such as applying an excess of pesticides. Here, we analyzed literature on the effects of the manipulation of plant diversity and habitats on the control of pests by arthropod and bird communities in apple, pear and peach orchards. Many investigations focus on the role of plant management to enhance biodiversity in orchards but only 22 research reports presenting 30 case studies were dedicated to the study of the ecosystem service provided by plant diversity for orchard pest control. The underlying mechanisms were seldom demonstrated, and the tested grass covers and tree assemblages aimed at favoring either the beneficial complex or only some beneficial species to control one or a few pests. The effect of plant management on pest control was mostly positive (16 cases) or null (9), but also negative in some cases (5). This finding reveals the difficulties of identifying selected plants or plant assemblages for the control of key pests. We conclude that further research is needed to identify the processes involved on different scales for biological control. Orchard systems should be re-designed to optimise ecosystem services provided by biodiversity.

195. Singh, M.M. 2001. Pollination ecology of common buckwheat (*Fagopyrum esculentum*) in different agro-ecozones of Nepal with particular reference to the role of the Himalayan honeybee, *Apis cerana.*, National Workshop on Research and Development on Buckwheat, Kathmandu (Nepal), 13-14 Sep. 2001. This paper presents the findings of two studies - one conducted on foraging behaviour of Himalayan honeybee (*Apis cerana* F.) on flowering buckwheat (*Fagopyrum esculentum* Moench) in November 2001 to 2002 and another on its impact on the grain quality and yield increment of this crop conducted during 2000-2002 under different pollination treatments at

Kirtipur, Kathmandu valley. *Apis cerana* bees started their foraging activities early in the morning (06.14} 0.004) and ceased late in the evening (17.28} 0.011). Total duration of foraging activity was 10:00 h and the average duration of foraging trip was 4.5} 0.14 min. Two peaks of foraging activities were observed between 08.30 to 10.30 (Peak I) and 11.30 to 13.30 O' clock (Peak II). The peak I period was the main foraging period and peak II was the second foraging period, both were very useful from the pollination point of view. After this, *Apis cerana* activity slowly diminished to a standstill at 17.30 pm. The time spent by *Apis cerana* on the buckwheat inflorescence at different hours of the day 09.00, 12.00, 15.00 O' clock showed longest (24) 3 min) in the morning and it decreased as the afternoon approached. This study revealed that *Apis cerana* bee pollination increased grain set in terms of the total number of grains per plant (169.76} 4.10), grain weight (33.03} 0.26 g) and grain yield (4.40} 0.12 g). It also increased the value of fertility (16.08} 0.21) and harvest index (35.32} 0.35) when compared with Control pollination/excluding all the insects (CP) and Open pollination (OP) treatment. This is mainly due to greater number of pollinators in the Bee pollination (BP) treatment, their longer duration of foraging and also due to superior pollinating efficiency of *Apis cerana* bees.

196. Six, J., S.D. Freyn, R.K. Thietn, and K. Batten. 2006. Bacterial and fungal contributions to carbon sequestration in agroecosystems. Soil Sci Soc Am J 70:555. doi:10.2136/sssaj2004.0347. This paper reviews the current knowledge of microbial processes affecting C sequestration in agroecosystems. The microbial contribution to soil C storage is directly related to microbial community dynamics and the balance between formation and degradation of microbial byproducts. Soil microbes also indirectly influence C cycling by improving soil aggregation, which physically protects soil organic matter (SOM). Consequently, the microbial contribution to C sequestration is governed by the interactions between the amount of microbial biomass, microbial community structure, microbial byproducts, and soil properties such as texture, clay mineralogy, pore-size distribution, and aggregate dynamics. The capacity of a soil to protect microbial biomass and microbially derived organic matter (MOM) is directly and/or indirectly (i.e., through physical protection by aggregates) related to the reactive properties of clays. However, the stabilization of MOM in the soil is also related to the efficiency with which microorganisms utilize substrate C and the chemical nature of the byproducts they produce. Crop rotations, reduced or no-tillage practices, organic farming, and cover crops increase total microbial biomass and shift the community structure toward a more fungal-dominated community, thereby enhancing the accumulation of MOM. A quantitative and qualitative improvement of SOM is generally observed in agroecosystems favoring a fungal-dominated community, but the mechanisms leading to this improvement are not completely understood. Gaps within our knowledge on MOM-C dynamics and how they are related to soil properties and agricultural practices are identified.

197. Smith, P. 2012. Soils and climate change. Current Opinion in Environmental Sustainability, 4(5), 539–544. https://doi.org/10.1016/j.cosust.2012.06.005. Soils contain vast reserves (~1500 Pg C) of carbon, about twice that found as carbon dioxide in the atmosphere. Historically, soils in managed ecosystems have lost a portion of this carbon (40–90 Pg C) through land use change, some of which has remained in the atmosphere. In terms of climate change, most projections suggest that soils carbon changes driven by future climate change will range from small losses to moderate gains, but these global trends show considerable regional variation. The response of soil C in future will be determined by a delicate balance between the impacts of increased temperature and decreased soil moisture on decomposition rates, and the balance between changes in C losses from decomposition and C gains through increased productivity. In terms of using soils to mitigate climate change, soil C sequestration globally has a large, cost-competitive mitigation potential. Nevertheless, limitations of soil C sequestration include time-limitation, non-permanence, displacement and difficulties in verification. Despite these limitations, soil C sequestration can be useful to meet short-term to medium-term targets, and confers a number of co-benefits on soils, making it a viable option for reducing the short term atmospheric CO2 concentration, thus buying time to develop longer term emission reduction solutions across all sectors of the economy.

198. Soulé, M. 2013. The "new conservation." *Conservation Biology* 27.5: 895-897. This editorial describes the new conservation as a movement that goes beyond the protection of biodiversity and instead seeks to enhance those natural systems that benefit the widest number of people, especially the poor. The author criticized this approach, and stated that if implemented, this type of conservation would hasten ecological collapse globally.

199. Sridhar, V., K.S. Nitin, R. Asokan and A. Adiga. 2017. Use of CLIMEX to identify the potential areas for spread of *Tuta absoluta* under climate change. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. *Tuta absoluta* is an oligphagous pest on solanaceous crops having a potential of causing 100% damage in tomato. Though it is of South American origin recently invaded other countries in Europe, Africa and Asia in recent years. In 2014 and 2016, it was reported from India and Nepal, respectively. Changing climatic conditions could favor its distribution in other parts of Asia. By using a bioclimatic software CLIMEX, it is possible to predict distribution of *T. absoluta* with reference to 1^{0}C, 2^{0}C and 3^{0}C rise in temperature in different parts of the world with particular reference to India and Nepal. Various implications of climate change on *T. absoluta* potential spreads are included in this presentation.

200. Swift, M.J., O. Andrén, L. Brussaard, M. Briones, M.-M. Couteaux, K. Ekschmitt, A. Kjoller, P. Loiseau, and P. Smith. 1998. Global change, soil biodiversity, and nitrogen cycling in terrestrial ecosystems: Three case studies. Global Change Biology, 4(7), 729–743. https://doi.org/10.1046/j.1365-2486.1998.00207.x. The relative contribution of different soil

organism groups to nutrient cycling has been quantified for a number of ecosystems. Some functions, particularly within the N-cycle, are carried out by very specific organisms. Others, including those of decomposition and nutrient release from organic inputs are, however, mediated by a diverse group of bacteria, protozoa, fungi and invertebrate animals. Many authors have hypothesized that there is a high degree of equivalence and flexibility in function within this decomposer community and thence a substantial extent of redundancy in species richness and resilience in functional capacity. Three case studies are presented to examine the relationship between soil biodiversity and nitrogen cycling under global change in ecosystem types from three latitudes, i.e. tundra, temperate grassland and tropical rainforest. In all three ecosystems evidence exists for the potential impact of global change factors (temperature change, CO_2 enrichment, land-use-change) on the composition and diversity of the soil community as well as on various aspects of the nitrogen and other cycles. There is, however, very little unequivocal evidence of direct causal linkage between species richness and nutrient cycling efficiency. Most of the changes detected are shifts in the influence of major functional groups of the soil biota (e.g. between microflora and fauna in decomposition). There seem to be few data, however, from which to judge the significance of changes in diversity within functional groups. Nonetheless the soil biota are hypothesized to be a sensitive link between plant detritus and the availability of nutrients to plant uptake. Any factors affecting the quantity or quality of plant detritus is likely to change this link. Rigorous experimentation on the relationships between soil species richness and the regulation or resilience of nutrient cycles under global change thus remains a high priority.

201. Stringer, L.D. R. Soopaya, and R.C. Butler *et al*. 2019. Effect of Lure Combination on Fruit Fly Surveillance Sensitivity. Sci. Rep. 9:2653. https://doi.org/10.1038/s41598-018-37487-6. Surveillance for invading insect pests is costly and the trapper usually finds the traps empty of the target pest. Since the successful establishment of new pests is an uncommon event, multiple lures placed into one trap might increase the efficiency of the surveillance system. We investigated the effect of the combination of the Tephritidae male lures – trimedlure, cuelure, raspberry ketone and methyl eugenol – on catch of *Ceratitis capitata*, *Zeugodacus cucurbitae*, *Bactrocera tryoni*, B. dorsalis, *B. aquilonis* and *B. tenuifascia* in Australia and the USA (not all species are present in each country). The increase in trap density required to offset any reduction in catch due to the presence of lures for other Tephritidae was estimated. The effect of increasing trap density to maintain surveillance sensitivity was modelled for a hypothetical population of B. tryoni males, where the effective sampling area of cuelure traps for this species has been estimated. The 3-way combination significantly reduced the catch of the methyl eugenol-responsive B. dorsalis. Unexpectedly, we found that trimedlure-baited traps that contained methyl eugenol had ×3.1 lower catch of *C. capitata* than in trimedlure-only-baited traps in Australia, but not in Hawaii where no difference in catch was observed, we cannot satisfactorily explain this result. Based on the data

presented here and from previous research, combinations of some male lures for the early detection of tephritid flies appear compatible and where there is any reduction in surveillance sensitivity observed, this can be offset by increasing the density of traps in the area.

202. Szabo, T.I., Smith, M.V. 1970. The use of *Megachile rotundata* for the pollination of greenhouse cucumbers. Pages 95-103 in The Indispensable Pollinators. editors. A Report of the 9th Pollination Conference. Hot Springs, Arkansas, October 1970. University of Arkansas Agricultural Extension Service.

203. TEEB. 2010. *Mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB*. Geneva: TEEB. This report synthesized the incorporation of economic concepts in decision making regarding environmental management. TEEB presented an approach that captures multiple economic values of nature, including various techniques for their assessment. The authors made the case for systematic appraisal of the economic contribution of biodiversity and ecosystem services to human well-being.

204. Thapa, R. B. 2006. Impact assessment of beekeeping program: A case study of selected VDCs of Kaski district, Nepal ICIMOD, Lalitpur, Nepal.

205. Thapa, R.B. 2006. Honeybees and other insect pollinators of cultivated plants, A review. J. Inst. Agric. Anim. Sci. 27:1-23. Insects are viewed from the harmful perspectives and aimed at killing them through several means including indiscriminate use of deadly chemicals. If good judgment made keeping views on sustainable crop production, natural balance and pollution free environment, they are important component of the ecosystem and their beneficial aspects are immense. One of them is that insects provide pollination service to plants. The study showed that over 50 species of insects visited flowers of 17 different species of selected crops during flowering periods. The visiting preferences of insects to flowers of different crops differed among the crop species and insect species as well. In fact, of the total pollination activities, over 80% is performed by insects and bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators. The manmade agro-ecosystem exerted pressure and forced to decline pollinators and their diversity, which resulted in reduced agricultural productivity again threatening biodiversity. Management of wide diversities of honeybees and other beneficial insects and flowering plant species occurring in Nepal help to maintain diversity of flora and bee fauna, pollination and reward hive products in the service of mankind. This paper covers honeybees and other insect species visiting various crop flowers.

206. Thapa, R.B., S. Pokhrel and S. Tiwari. 2008. Agrochemical database of Field and Home garden crops in Chitwan, Nepal. Proceedings of the Workshops on Conservation and Management of Pollinators for Sustainable agriculture through and Ecosystem Approach - Global Pollinator

Project/Pilot Activities. *In:* R.B Thapa (ed.) Global Pollinator Project-FAO/UNDP and Institute of Agriculture and Animal Sciences, Rampur Chitwan Nepal. pp. 22-23.

207. Thapa, R.B., S. Pokhrel and S. Tiwari. 2008. Bibliography of pesticides, buckwheat and Mustard. Proceedings of the Workshops on Conservation and Management of Pollinators for Sustainable agriculture through and Ecosystem Approach - Global Pollinator Project/Pilot Activities. *In:* R.B Thapa (ed.) Global Pollinator Project-FAO/UNDP and Institute of Agriculture and Animal Sciences, Rampur Chitwan Nepal. pp. 24-25.

208. Thapa, R.B., S. Pokhrel and S. Tiwari. 2008. Field Experiment on Pollination Management in Chitwan,Nepal. Proceedings of the Workshops on Conservation and Management of Pollinators for Sustainable agriculture through and Ecosystem Approach - Global Pollinator Project/Pilot Activities. *In:* R.B Thapa (ed.) Global Pollinator Project-FAO/UNDP and Institute of Agriculture and Animal Sciences, Rampur Chitwan Nepal. pp. 30-36.

209. Thapa, R.B., S. Pokhrel and *S. Tiwari*. 2008. Good Pollination Practices Adopted by the farmers in Chitwan, Nepal. Proceedings of the Workshops on Conservation and Management of Pollinators for Sustainable agriculture through and Ecosystem Approach - Global Pollinator Project/Pilot Activities. *In:* R.B Thapa (ed.) Global Pollinator Project-FAO/UNDP and Institute of Agriculture and Animal Sciences, Rampur Chitwan Nepal. pp. 37-43.

210. Thapa, R.B., S. Pokhrel and S. Tiwari. 2008. Insect Flower visitors on Buckwheat, Bittergourd and Mustard in Chitwan,Nepal. Proceedings of the Workshops on Conservation and Management of Pollinators for Sustainable agriculture through and Ecosystem Approach - Global Pollinator Project/Pilot Activities. *In:* R.B Thapa (ed.) Global Pollinator Project-FAO/UNDP and Institute of Agriculture and Animal Sciences, Rampur Chitwan Nepal. pp. 28-29.

211. Thapalya, S. 2017. Hot is here: Climate change and its impact on biodiversity. Abstract of the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, 10-12 January 2017, Kathmandu, Nepal. Food and biodiversity, and lack of it, could be where a challenging climate exerts some of its most troublesome impacts in society. Climate change is more vulnerable impact in developing countries like Nepal. The rapidly retreating glaciers (30m/yr), rise in temperature (>0.06 ^{0}C), erratic rainfall are the situations Nepal is facing today. Biodiversity is also being affected as useful flora, fauna, medicinal, food and nutrition related plants may disappear. For example average crop yield is expected to drop down to 50% in Pakistan, whereas cron production in Europe is expected up to 25%. Where CO2 was increased over present day level by about 50%, the yield rose by 7% for rice and 8% for wheat. The adverse impacts can be mitigated through COP, Kyoto protocol, social awareness and by other different political methodology.

212. Thayer, A.W., A. Vargas, A.A. Castellanos, C.W. Lafon, B.A. McCarl, D.L. Roelke, K.O. Winemiller, and T.E. Lacher. 2020. Integrating agriculture and ecosystems to find suitable adaptations to climate change. Climate, 8(1), 10. https://doi.org/10.3390/cli8010010. Climate change is altering agricultural production and ecosystems around the world. Future projections indicate that additional change is expected in the coming decades, forcing individuals and communities to respond and adapt. Current research efforts typically examine climate change effects and possible adaptations but fail to integrate agriculture and ecosystems. This failure to jointly consider these systems and associated externalities may underestimate climate change impacts or cause adaptation implementation surprises, such as causing adaptation status of some groups or ecosystems to be worsened. This work describes and motivates reasons why ecosystems and agriculture adaptation require an integrated analytical approach. Synthesis of current literature and examples from Texas are used to explain concepts and current challenges. Texas is chosen because of its high agricultural output that is produced in close interrelationship with the surrounding semi-arid ecosystem. We conclude that future effect and adaptation analyses would be wise to jointly consider ecosystems and agriculture. Existing paradigms and useful methodology can be transplanted from the sustainable agriculture and ecosystem service literature to explore alternatives for climate adaptation and incentivization of private agriculturalists and consumers. Researchers are encouraged to adopt integrated modeling as a means to avoid implementation challenges and surprises when formulating and implementing adaptation.

213. Thomas Bjorkman and Pearson. K 1995. The Inefficiency of. Honeybees in the Pollination of Buckwheat. Current Advances in Buckwheat Research (1995): 453–462. Seed production in buckwheat (*Fagopyrum esculentum* Moench) can be much lower than expected from the plant biomass, and this low seed production has been blamed on inadequate pollination. Honey bees (Apis melli/era L.) were at least 95% of the insect visitors to buckwheat flowers in fields of central New York State. The number of times each flower was visited by a honey bee ranged from zero to over 40, but there was no relationship between the number of bee visits and the daily seed initiation if there were at least two. Pollen delivery sometimes limited seed set, but limitation was not associated with low bee activity. Buckwheat performs best with pollen deliveries of at least 10 grains, but bees delivered small quantities. The time between delivery of the first pollen grain and the tenth was about an hour, more than enough for fertilization to have occurred. Pollination of buckwheat in New York is accomplished primarily by honey bees, but their pollination behavior is not well-adapted to the crop, and their effectiveness is not improved at higher populations.

214. Thomas, G.A., Dalal, R.C., and J. Standley. 2007a. No-till effects on organic matter, pH, cation exchange capacity and nutrient distribution in a Luvisol in the semi-arid subtropics. Soil Tillage Res 94:295–304. https://doi.org/10.1016/ j.still.2006.08.005. No-till (NT) system for grain cropping is increasingly being practiced in Australia. While benefits of NT, accompanied by

stubble retention, are almost universal for soil erosion control, effects on soil organic matter and other soil properties are inconsistent, especially in a semi-arid, subtropical environment. We examined the effects of tillage, stubble and fertilizer management on the distribution of organic matter and nutrients in the topsoil (0–30 cm) of a Luvisol in a semi-arid, subtropical environment in southern Queensland, Australia. Measurements were made at the end of 9 years of NT, reduced till (RT) and conventional till (CT) practices, in combination with stubble retention and fertilizer N (as urea) application strategies for wheat (*Triticum aestivum* L.) cropping. In the top 30 cm depth, the mean amount of organic C increased slightly after 9 years, although it was similar under all tillage practices, while the amount of total N declined under CT and RT practices, but not under NT. In the 0–10 cm depth, the amounts of organic C and total N were significantly greater under NT than under RT or CT. No-till had 1.94 Mg ha−1 (18%) more organic C and 0.20 Mg ha−1 (21%) more total N than CT. In the 0–30 cm depth, soil under NT practice had 290 kg N ha−1 more than that under the CT practice, most of it in the top 10 cm depth. Microbial biomass N was similar for all treatments. Under NT, there was a concentration gradient in organic C, total N and microbial biomass N, with concentrations decreasing from 0–2.5 to 5–10 cm depths. Soil pH was not affected by tillage or stubble treatments in the 0–10 cm depth, but decreased significantly from 7.5 to 7.2 with N fertilizer application. Exchangeable Mg and Na concentration, cation exchange capacity and exchangeable Na percentage in the 0–10 cm depth were greater under CT than under RT and NT, while exchangeable K and bicarbonate-extractable P concentrations were greater under NT than under CT. Therefore, NT and RT practices resulted in significant changes in soil organic C and N and exchangeable cations in the topsoil of a Luvisol, when compared with CT. The greater organic matter accumulation close to the soil surface and solute movement in these soils under NT practice would be beneficial to soil chemical and physical status and crop production in the long-term, whereas the concentration of nutrients such as P and K in surface layers may reduce their availability to crops.

215. Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature, 418(6898), 671–677. A doubling in global food demand projected for the next 50 years poses huge challenges for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services they provide to society. Agriculturalists are the principal managers of global useable lands and will shape, perhaps irreversibly, the surface of the Earth in the coming decades. New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if we are to meet the demands of improving yields without compromising environmental integrity or public health.

216. Tisdall, J.M. 1994. Possible role of soil microorganisms in aggregation in soils. Plant Soil 159:115–121. In many soils, roots and fungal hyphae, especially those of vesicular arbuscular mycorrhizal (VAM) fungi, stabilize macro-aggregates (>250 μm diameter); organic residues,

bacteria, polysaccharides and inorganic materials stabilize micro-aggregates (<250 μm). This review discusses the factors (including other organisms) which affect VAM hyphae and their extracellular polysaccharides in soil, and the subsequent effect on stability of aggregates. The review also discusses the possible role of other organisms, including ectomycorrhizal fungi, in the stability of soil, and suggests future research.

217. Tooker, J.F., M.E. O'Neal, and C. Rodriguez-Saona. 2020. Balancing Disturbance and Conservation in Agroecosystems to Improve Biological Control. Annu. Rev. Entomol. 65:81–100. https://doi.org/10.1146/ annurev-ento-011019-025143. Disturbances associated with agricultural intensification reduce our ability to achieve sustainable crop production. These disturbances stem from crop-management tactics and can leave crop fields more vulnerable to insect outbreaks, in part because natural-enemy communities often tend to be more susceptible to disturbance than herbivorous pests. Recent research has explored practices that conserve natural-enemy communities and reduce pest outbreaks, revealing that different components of agroecosystems can influence natural-enemy populations. In this review, we consider a range of disturbances that influence pest control provided by natural enemies and how conservation practices can mitigate or counteract disturbance. We use four case studies to illustrate how conservation and disturbance mitigation increase the potential for biological control and provide co-benefits for the broader agroecosystem. To facilitate the adoption of conservation practices that improve top-down control across significant areas of the landscape, these practices will need to provide multifunctional benefits, but should be implemented with natural enemies explicitly in mind.

218. Walmsley, A. and A. Cerdà. 2017. Soil macro-fauna and organic matter in irrigated orchards under Mediterranean climate. Biol. Agric. Hort. 2017, 33, 247–257. https://doi.org/10.1080/01448765. 2017.1336486. Soil fauna abundance and diversity and organic matter content are key indicators for the rate of soil degradation in Mediterranean-type ecosystems. The soil macro-fauna populations were examined in three orange (*Citrus sinensis*) orchards and one persimmon (*Diospyros kaki*) orchard, with the same soil type and different management systems, to establish whether organic management benefits soil fauna and soil quality and what is the effect of flood irrigation. Vegetation cover, soil organic matter, bulk density and moisture were measured at each experimental site within the Canyoles watershed in Eastern Spain in summer of 2015. Earthworm abundance was highest at the organic orchard with flood irrigation, followed by the organic orchard with drip irrigation, with juvenile endogeic earthworms being the dominant group. Soil isopoda was the dominant group of the arthropod macro-fauna, with highest abundance in the drip-irrigated organic orchard. Earthworm presence was highest in the flood-irrigated orchard, whereas soil arthropoda abundance was highest at the drip-irrigated organic site, where a thick litter layer was present. The soil organic matter was higher and soil bulk density lower at the organic orchards sites compared to conventional ones. The results suggested that organic farming

was beneficial for soil biological activity, though the conversion from flood to drip irrigation can have a negative impact on earthworms, which may cause a decrease in infiltration capacity of the soil.

219. Wiesmeier, M., L. Urbanski, E. Hobley, B. Lang, M. von Lützow, E. Marin-Spiotta, B. van Wesemael, E. Rabot, M. Ließ, and N. García-Franco, *et al*. 2019. Soil organic carbon storage as a key function of soils—A review of drivers and indicators at various scales. Geoderma 2019, 333, 149–162. https://doi.org/10.1016/j.geoderma.2018.07.026. The capacity of soils to store organic carbon represents a key function of soils that is not only decisive for climate regulation but also affects other soil functions. Recent efforts to assess the impact of land management on soil functionality proposed that an indicator- or proxy-based approach is a promising alternative to quantify soil functions compared to time- and cost-intensive measurements, particularly when larger regions are targeted. The objective of this review is to identify measurable biotic or abiotic properties that control soil organic carbon (SOC) storage at different spatial scales and could serve as indicators for an efficient quantification of SOC. These indicators should enable both an estimation of actual SOC storage as well as a prediction of the SOC storage potential, which is an important aspect in land use and management planning. There are many environmental conditions that affect SOC storage at different spatial scales. We provide a thorough overview of factors from micro-scales (particles to pedons) to the global scale and discuss their suitability as indicators for SOC storage: clay mineralogy, specific surface area, metal oxides, Ca and Mg cations, microorganisms, soil fauna, aggregation, texture, soil type, natural vegetation, land use and management, topography, parent material and climate. As a result, we propose a set of indicators that allow for time- and cost-efficient estimates of actual and potential SOC storage from the local to the regional and subcontinental scale. As a key element, the fine mineral fraction was identified to determine SOC stabilization in most soils. The quantification of SOC can be further refined by including climatic proxies, particularly elevation, as well as information on land use, soil management and vegetation characteristics. To enhance its indicative power towards land management effects, further "functional soil characteristics", particularly soil structural properties and changes in the soil microbial biomass pool should be included in this indicator system. The proposed system offers the potential to efficiently estimate the SOC storage capacity by means of simplified measures, such as soil fractionation procedures or infrared spectroscopic approaches.

220. Wilcove, D. S., and J. Lee. 2004. Using economic and regulatory incentives to restore endangered species: Lessons learned from three new programs. *Conservation Biology* 18.3:639-645. This article investigated the effectiveness of three incentive-based programs for restoring endangered species on private lands in the United States. The authors found that the "safe harbor" provision of the US Endangered Species Act and Environmental Defense's Landowner Conservation Assistance program both yielded conservation on private lands.

221. Williams, I.H., Martin, A.P., White, R.P. 1986. The pollination requirements of oil-seed rape (*Brassica napus* L). J. Agric. Sci. Camb. 106:27-30.

222. Williams, I.H., Martin, A.P., White, R.P. 1987. The effect of insect pollination on plant development and seed production in winter oil-seed rape (*Brassica napus* L). J.Agric.Sci.Camb. 109:135-139.

223. Yardim, E. and C. Edwards. 2002. Effects of weed control practices on surface-dwelling arthropod predators in tomato agroecosystems. Phytoparasitica 30:379–386. Weed control, an important practice in agroecosystems to protect crop production, is usually achieved with herbicides. However, these pesticides are expensive, pose potential risks to the environment, may affect some beneficial organisms indirectly, and decrease overall arthropod biodiversity, including pests and their natural enemies, by removing weeds that might act as hosts or shelters for many organisms. The activity density response of important surface-dwelling arthropod predators (ground beetles [Coleoptera: Carabidae], ants [Hymenoptera: Formicidae] and spiders [Arachnida: Araneae]) to herbicides (trifluralin and paraquat), and to two alternative weed management practices (rye straw mulch and mechanical treatment to maintain weeds below threshold levels, in comparison with an untreated check), was assessed using pitfall traps. The mulch treatment had the greatest effect on activity density, reducing the number of predators trapped significantly ($P<0.05$). Herbicide use resulted in significant ($P<0.05$) reductions in the activity density of ground beetles. Most predators were trapped in the check plots — which had the highest weed biomass, followed in turn by numbers trapped in the threshold weed control treatment, the full herbicide application and the mulch treatment plots.

224. Wunder, S. 2005. Payments for environmental services: Some nuts and bolts. *CIFOR Occasional Paper* 1-24. This report defined the payments for ecosystem services and provides suggestions for PES design. It is an assessment based on a literature review with observation from field research conducted in Latin America and Asia. The conclusions on the report state that users will continue to drive PES, but their willingness to pay will only increase if schemes can demonstrate clear additionality.Yardim E, Edwards C (2002) Effects of weed control practices on surface-dwelling arthropod predators in tomato agroecosystems. Phytoparasitica 30:379–386. Weed control, an important practice in agroecosystems to protect crop production, is usually achieved with herbicides. However, these pesticides are expensive, pose potential risks to the environment, may affect some beneficial organisms indirectly, and decrease overall arthropod biodiversity, including pests and their natural enemies, by removing weeds that might act as hosts or shelters for many organisms. The activity density response of important surface-dwelling arthropod predators (ground beetles [Coleoptera: Carabidae], ants [Hymenoptera: Formicidae] and spiders [Arachnida: Araneae]) to herbicides (trifluralin and paraquat), and to two alternative weed management practices (rye straw mulch and mechanical treatment to maintain weeds below

threshold levels, in comparison with an untreated check), was assessed using pitfall traps. The mulch treatment had the greatest effect on activity density, reducing the number of predators trapped significantly ($P<0.05$). Herbicide use resulted in significant ($P<0.05$) reductions in the activity density of ground beetles. Most predators were trapped in the check plots — which had the highest weed biomass, followed in turn by numbers trapped in the threshold weed control treatment, the full herbicide application and the mulch treatment plots.

225. Wunder, S. 2005. Payments for environmental services: Some nuts and bolts. *CIFOR Occasional Paper* 1-24. This report defined the payments for ecosystem services and provides suggestions for PES design. It is an assessment based on a literature review with observation from field research conducted in Latin America and Asia. The conclusions on the report state that users will continue to drive PES, but their willingness to pay will only increase if schemes can demonstrate clear additionality.

3.6 Recommend the best conservation and management package of practices for agro-ecosystem services for apple, mustard, buckwheat, citrus etc.

3.6.1 Introduction

Agriculture has been considered as the backbone of the national economy, food security of the country and livelihood of farm families. Farmers have recognized the accessibility of favorable biological and agro-ecological environmental opportunities to produce crops in different agro ecological regimes. However, both biotic and abiotic factors affect crop production. Increasing trend in external input uses mainly chemical fertilizers and pesticides and depleting soil fertility affect crop production and lack of knowledge among the farmers on the fate of chemicals used in the crop production has been observed to be the root cause of poisoning and environment pollution. Lately there is growing concern of chemical residue in foods. Therefore, it is necessary to produce crops without depleting soil fertility, without pesticide residue on the produce thereby creating a healthy agro-ecosystem for maintaining diversity and conservation of all organisms for getting good ecosystem services. The practices begin from soil preparation to harvesting of crops.

3.6.2 Objectives

- To aware farmers and consumers on the importance of crop production technology.
- To extend eco-friendly production technologies of individual crops to farmers for maximizing crop production and productivity.
- To solve food insecurity and secure food security with a balanced diet for people.
- To document best management practices for development agents and farmers who are engaged in crop production.
- To use the crop production package as a practical guide for investors, experts, and development agents.

- To supply raw materials for agro industries.

3.6.3 Production factors and management practices

1.1 Abiotic factors affecting crop production

- Fertile soil and water are essential for good seed germination and plant growth.
- Optimum light, temperature and humidity are necessary for plant growth, development of microbes, like bacteria, fungi, viruses, and insects like predators, parasites, pollinators and decomposers, in addition, wind for dispersion of seed of plant, pests and change in crop growth and production.
- Balanced fertilizer and bio-rational pesticide are essential for plant growth and pest protection.

1.2 Biotic factors affecting crop production

- Plants (vegetable or weed or trees) compete for nutrients, lights and acts as host for beneficial and harmful organisms.
- Insects and micro-organisms (both beneficial and harmful) interact with plants and influence growth and production.
- Other vertebrates, including birds and wildlife either cause pest problems or help for pest control and play role in nutrient cycle.

1.3. Crop production technology supports sustainable agro-ecosystems services.

- Ensure safe and nutritional food production.
- Maintain biodiversity in farming systems.
- Judicious use of chemical pesticides and chemical fertilizer.
- Maintain long term fertility of soil.
- Use of renewable resources in crop production systems.
- Reduction of all forms of pollution during agricultural operations.

1.4. Agroecosystem based crop production and management practices

1.4.1 Basic practices

- Well decomposed FYM or compost and balanced fertilizer use.
- Use of effective microorganism (EM) for the compost.
- Use of the micronutrients and microorganism like Trichoderma, Beauveria and metarhizium in the soil preparation
- Good land preparation, field sanitation and hygienic condition.
- Use of quality seed/seedling/planting materials.
- Selection of pest/disease tolerant varieties and good planting/sowing time.
- Provide the irrigation on the appropriate time.
- Practice of appropriate cropping system (trap crop, mix crop, relay crop etc)

- Regular field monitoring for pest incidence, and timely use of bio-rational pest control measures.
- Restriction of chemicals listed as hazardous by GoN prohibited to use (red marked pesticides), rather choosing safer and newer eco-friendly pest control measures.
- Record keeping of all operations for analyzing cost benefit of farming.

1.4.2 Specific practices

1.4.2.1 *Cultural and physical measures*

- Planting distance and crop canopy as per crop and varieties.
- Host and non-host combination for pest and disease management.
- Appropriate tillage, residue management, preservation of organic matter in the soil.
- Practice timely irrigation to maintain optimum soil moisture.
- Use of mulch (biological and plastic materials) and intercropping to suppress pests and conserve soil moisture.
- Balanced use of well decomposed manure and chemical fertilizers as per recommendation of crops.
- Practice of growing crops inside tunnel to maintain temperature and restrict entry of pests.
- Practice of timely pest management practices.

1.4.2.2 *Mechanical measures*

- Digging, hand picking, pruning/removing pest or disease affected plant parts and destroying them.
- Sticky traps and light trap catches of pests.

1.4.2.3 *Biological measures*

- Disrupting pest mating, use of pheromone traps.
- Conservation of predators and parasites.
- Use of well decomposed compost for soil micro-floral activity.
- Use of botanical plant materials and their extracts.
- Use of microbial pesticides (entomo-pathogenic fungi, bacteria, virus, nematodes etc.), and hormonal analogues.

1.4.2.4 *Chemical measures*

- Use of blue and green label pesticides strictly following recommendation with personal safety precaution.
- Selection of appropriate pesticide and using the in the morning or in the evening.
- Following waiting period strictly after each chemical application.

1.4.3 General practices

It differs based on the crops, seasons and different crop growing regimes. However, a general procedure to be followed while growing crop is outlined here under.

1.4.3.1 *Field selection*

- Layout of the field for crop production.
- Regular soil test for pH, OM, NPK and nutrient management for maintaining soil fertility
- Crop rotation plan and practices with legume cropping pattern for soil fertility and pest management.
- Crop field with enough sunlight and well managed irrigation and drainage facility.
- Area free from pollution and protection from external enemies.

1.4.3.2 *Nursery management*

- Nursery site with enough sunlight and well managed irrigation and drainage facility.
- Area free from pollution and protection from external enemies.
- Soil solarization using chemical and plastic mulch before seeding.
- Use of well decomposed FYM or compost mixed with sand, wood ash (1.5 to 2 kg/m^2) for nursery raising.
- Healthy raising of saplings in raised bed or plastic cups using above soil or cocopeat.
- For producing fruit saplings, proper selection of rootstocks and good size of scions and raising them for at least 6-12 months before transplanting.
- Regular monitoring and management of pests to produce pest free seedlings/saplings.

1.4.3.3 *Field soil management*

- Green manuring with legume or other approaches to maintain soil fertility.
- Preparation of lands according to requirement of crops.
- Use of recommended well decomposed FYM and balanced use of chemical fertilizer.
- Test of pH, organic matter and NPK once in two year or as per recommendation.
- Field soil improvement following crop rotation, avoiding same family crop as follow up crop, use of antagonistic crop for soil borne disease, nematodes or some soil insects, conservation tillage, mulch etc.
- Regular monitoring and management of pests.

1.4.3.4 *Planting and production*

- Spacing varies from crop to crop, so follow the spacing as per the recommendation.
- Use pest/pathogen free planting materials from recommended nursery or quality seeds.
- Use of recommended well decomposed FYM and balanced use of chemical fertilizer for growing crops.
- Timely irrigation with drainage facility and intercultural operation for healthy crop production.
- Regular monitoring and management of pests and timely harvest of crops.

1.4.3.5 *Pest management*

- Regular monitoring of crop field to identify pests problems and beneficial bioagents of the pests.
- Practice diversification of farm landscape for maintaining diversity and conservation of bioagents.
- Intercropping with *Tagates petula* that suppress nematode and plant like mint, basil repellent pests.
- Maintain inter-linkage with other elements like shade, mulch and intercropping/habitat.
- Use neem & other plant extracts, petroleum oil based Servo, jholmol to repel insect pests, and microbial pesticides to manage insect pests.
- Use mineral extracts like lime/sulfur to suppress diseases.
- Use colored traps, light traps for monitoring insect pests.
- Use rodent baits for controlling house and field rats.
- Read carefully label of pesticides, their dose, safety measures, and waiting period after spray in the field.

1.4.3.6 *Pollinators management*

- Scale up beekeeping among farmers for managed crop pollination and various hive production.
- Use native flowering plants that are adopted to local climate, soil and growing seasons.
- Choose nectar and pollen-rich plants like wild flowers attractive to pollinators.
- Select diverse color and flower structure that attract multi-pollinators.
- Create habitat for nesting, like grounds, branches, tall grasses and shrubs.
- Never use pesticides during flowering, which kill pollinators.
- Maintain flowers that bloom through the growing season.
- Provide foods and water sources, which are necessary to pollinators.
- Adopting good agriculture practices (i.e. IPM/IDM, organic farming, community forestry, declaration of protected area, and establishing biodiversity garden etc.)
- Avoiding bad practices (i.e. over-grazing, honey hunting, slash-burning, deforestation, firing, soil erosion, multiple tillage, flooded irrigation, use of agro chemicals, mono cropping etc.).

1.4.3.7 *Climate change resilience*

- Identifying and using various cropping patterns to promote integrated and long-term conservation.
- Cropping with agro-forestry in mitigating climate change by sequestrating carbon and in regulating weather patterns.
- Helping farmers to plant new crops and seeds, build home garden, practice mixed farming, establish community seed banks, and multi-use water systems.

- Improving current practices of in situ conservation of crop and livestock genetic resources, using local seeds and research and promotion of adaptive traits of local crops to help farmers.
- Awareness and training farmers on ecosystem-based approaches to tackle current and future climate change impacts.
- Funding to increased research, monitoring, and conservation efforts.
- Integrating climate-change adaptation into existing planning processes.

1.4.3.8 *Harvest and post-harvest management*

- Consider crop maturity appearance, texture soft/coarse, rigidity, aroma, taste, season and marketing.
- Use appropriate tools (sickle/cutter, scissors, etc.) or hand picking to harvest the crops.
- Collect and keep the products in appropriate and hygienic condition.
- Protect from sunlight, rain, dust or other unwanted elements and possible microbial contact.
- Proper grading, cleaning and packing of produce in appropriate container before storing or marketing.
- Calculation of production cost, selling price and net benefits to the farmers.

3.6.4 Crop specific practices

Agro-technological practices imply all activities which need to be undertaken for development of specific agricultural crops, like land preparation, soil fertility, crop varieties, sowing, inter-culture practices, bio-rational pest management and harvesting of crops with least disruption to the environment. Over 2/3rd of Nepal’s population depends on agriculture, which is highly climate sensitive and increasingly at risk from climate change impacts and so needs serious thinking. Key effects of climate change on agriculture include declining water availability for irrigation, increasing peak flood flows, changing pest status and declining crop yields. For example, 4°C increase in temperature would lead to increase in rice yield in the terai by 3.4%, in the hills by 17.9% and in the mountains by 36.1%. At the same time, climate change can delay crop maturity and destroy local species. Thus, climate change will not only affect eco- biodiversity but also the livelihood of millions of people who depend on it. These all in harmony keep balance in crop production and maintaining diversity of all in an agro-ecosystem (Refer Annexes). This eco-friendly farming practices aims to address present challenges related to: i) conservation and management of ecosystem services and the population of natural enemies, beneficial organism, pollinators, decomposers and symbiotic agents; ii) increase the crop yield and farm income through the restoration of agro-ecosystem services to attain the of goal of sustainable agriculture; and iii) enhancing food security and nutrition and can contribute to ecological resilience against climate change extremes and environmental degradation.

3.6.4.1 Apple (*Malus domestica* Borkh.)

Background

The apple is an important temperate fruit and is grown in area where winter is cold, springs frost free and summer mild. It is commercially a most important temperate fruit, which is widely produced in the world after orange, banana and grape. It can be grown at an altitude of 1800-2800masl.

In Nepal, apple is grown in selected districts of high hill region. Commercial apple production is done in Jumla, Mugu, Kalikot Mustang, and part of Rasuwa, Sindhupalchok, Dolakha, Solukhumbu, Rukum, Rolpa. It has covered 5,674 ha of land with production and productivity of 48,946 mt and 8.63 mt/ha, respectively (MOAD, 2018). The apples from high hills have high export potential, which can earn foreign currency and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance

1. Apple farming is an important source of income for the high hill farmers.
2. Apple farming occupies an important place in fruit development in the country.
3. It is important fruit for health; fruit is rich in carbohydrate (15%) protein (0.3 %) and nutrients, like K, P & Ca.
4. It is exportable fruit to foreign countries, which provide an opportunity for earning foreign exchange.
5. Organic apple farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

The apple is an important temperate fruit in the world. Apple production dominating countries are New Zealand, USA, Brazil, Chili and some EU countries (i.e. France and Italy), where the annual yields range between 20 to 50 mt /ha/yr (FAO, 2016). Although China ranks in the first in fruit industry in terms of growing area, but its production is low. In 1990 it was less than 5 mt/ha/yr and even in 2015 the productivity has remained less than 20 mt/ha/yr. In 2014/15, the national production of fruit was 8.96 mt/ha and apple 7.8 mt/ha in Nepal (MoAC 2016). This productivity is very low and many problems are associated with low productivity, mainly due to farmers' traditional practices rather than following improved practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

Worldwide climate has a significant effect on citrus yield, growth, fruit quality and economic returns. Apple production in Morocco is highly affected by pests and adverse weather conditions (Moinina et al., 2018). For example, apple production decreased due to pests, temperature and rainfall fluctuations by 40% in 2016. In Nepal, the average fruit yield has been estimated 6.25 mt/ha based on the farmers' answers and this yield is less by 3.32 mt/ha if compared with national average of 9.5 mt/ha (Shahi, 2005).

Intercropping study in Kasmir India, has shown significant improvement in Red delicious apple trees intercropped with legumes followed by control and non-legume type crop (Bhat et al., 2018). For example, Fruit yield (37.51 kg/tree), fruit weight (155.72g), fruit volume (165.56 cm3) and leaf nutrient status, N P, K, Ca and Mg with higher B:C ratio were found to be highest in trees intercropped with legumes than with the non-legume type of crops.

In pest management, while reviewing for 100 years, orchard monitoring, pheromone traps, economic thresholds, and degree-day models are practiced by growers, and use of alternate row spraying, biological control, and reduced chemical rates have all increased dramatically in US (Brunner et al., 2003).

Integrated pest management was always better option apple orchard in Kentaky, USA (Bessin, 1994).

Mite density was positively related to the total grams AI (or number of applications) of acetamiprid, and thus reducing the number of applications per season lower the probability of mite outbreaks, which decreased from six sprays to only 2 sprays in US apple orchard (Beers et al., 2005).

After the application of selective insecticides rather than broad spectrum insecticides the arthropod diversity increased in apple orchard in Hungary (Jenser et al., 1999). Adoption level of IPM practice was estimated to increase by 45.8% in Mustang if training provided to farmers and 53% farmers were satisfied with the practice (Ghimire and Kafle, 2014).

Honey bee colonies (2-3 colonies) in apple orchard beginning 10% to over 90% flowering. However in Kasmir India, 86.5% of apple growers are unaware of compatible pollenizer variety and 60-70% doesn't know about the important role of honey bees in apple production (Rather et al., 2017). Among the two domesticated species of honey bees studied in Kashmir valley, *A. cerana* foraged for a significantly longer time, reached its peak activity, visited more flowers per minute and took greater time for completing a single forging trip on apple bloom than *A. mellifera* (Ahmad et al., 2016). In US in context of CCD, out of about 450 other wild bees, over 100 of them visited apple orchard and their conservation was necessary (Parker et al., 2015). Apple pollination was studied through different modes by selfing by bagging, hand pollination, open pollination in Himanchal Pradesh, Red Baron' was fertilized with all the seven pollinizers tested and fruit set ranged from 86.2 to 92.4 % and retention from 58.5 to 86.2% (Sharma et al., 2014). According to Sheffield et al. (2016) apple production depends on insect pollination - therefore, understanding pollinators, their requirements and behaviors within and around apple orchards, at both small and large-scale production levels, will allow for better pollination management strategies and increase apple production. Therefore, for apple orchards with <15% pollinizers, 8 hives; orchards with >30% pollinizers, 2-3 hives and for high density planting adjustment needed accordingly (Verma, 2015).

In Europe, scientists have better opening for research towards IPM improvement, including the use of bio-rational pesticides, semio-chemicals and biological control including forecasting models, new tree training systems and innovative sprays (Damos et al., 2015).

Agriculture Policy of the European Union, is providing a good enabling environment for agriculture innovation and knowledge is transferred from innovation to farmers rapidly in Italy and apple production area in South Tyrol supplies up to 50% of the Italian apple market, 15% of the European and 2% of the global apple market (Meyer, 2014).

Production practices need to follow step-by-step from the beginning to end of apple production cycle to ensure healthy production and higher productivity, and farmers are not following properly, i.e. why they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice
1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Orchard health	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Training/pruning	Training/pruning to assure healthy orchard	Not following properly
4	Optimum soil pH	Lime application @ 5-7 kg/tree 15-30cm depth to correct acidic soil	Not following correctly
5	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
6	Micronutrient use	Based on soil analysis micronutrient use	Not following properly
7	Irrigation	Critical at veg growth, flower, fruiting stage	No facility or not following
8	Intercropping	Short duration legume crops, vegetables	No intercrop or other than legume crops
9	Pollinators use and conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of apple flowers
10	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
11	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality fruits	Poor care during harvest/ postharvest

Apple farmers groups

Three apple farming groups organized in the project district Mustang and oriented them in IPPM-FFS for production and management of apple:

- Planning for technology based apple orchards.
- Keeping prior history and yield of apple.
- Recording soil test, pH, OM, NPK.
- Selecting orchard and variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Nursery/ Orchard management

- Using rootstock- Crab apple or clonal rootstocks for good sapling production.
- Keeping nursery site & soil free from insect pests and diseases.
- Maintaining quality mother plants.
- Buying planting materials from reliable source/registered nursery.
- Maintaining appropriate planting distance (P-P 6m x 6m) in apple orchard.
- Preparing pit $1m^3$ size for planting of good quality sapling.

- Using compatible pollinizers well maintained in the orchard.
- Planting and maintaining windbreak trees around the orchard.
- Growing legume crops as intercropping to improve soil fertility, trap crops for insect pests and cover crops for moisture retention.

Manure and fertilizers

- Using balanced nutrients, a ten years mature apple tree requires 100 kg FYM, 400 gm N, 200 gm P, 80 gm K/plant (MOAD, 2016).
- The final dose of manure / fertilizer is decided as per the soil test result.
- Applying manure and fertilizer in the basin.
- Treated the FYM with the jivatu or EM.
- After 10th year, fertilizer use can be minimized gradually but use of organic manure, mulching needs to intensify.
- Foliar spray of major and micro nutrients in winter before bud initiation is necessary

Intercultural operation and irrigation

- Keeping basin area around the tree weed free with manual weeding and hoeing.
- Thinning fruits after June drop, usually leaving 3 fruits per spur for good quality fruits.
- Intercropping leguminous crops and seasonal vegetables, like green peas, beans, broad leaf mustard crops etc.
- Mulching especially during summer season to prevent weeds and moisture retension.
- Irrigating apple orchard in ring basin system after each fertilizer application.
- Drenching during summer (March to June) at least the 30cm soil depth.

Training/Pruning

- Removing water shoots, unwanted and overlapping and disease twigs and branches.
- Training/pruning of apple orchard considering the flowering and vegetative, buds space, nutrient, light and air.
- Applying Bordeaux paste on the cut surface after pruning and de-suckering from rootstocks.

Pest management

- Weekly monitoring as survey and surveillance to maintain the record of the pests.
- Promoting conservation of natural enemies by augmentation and inundation.

Cultural practices

- Practicing apple orchard sanitation.
- Irrigating timely for managing soil insects in the orchard.
- Using pest repellent flowers, like marigold, chrysanthemum depending upon the suitability around the apple orchard.
- Applying Bordeaux paste or other indigenous materials to cover cut/wounds.
- Avoiding injuries to roots or collar of trees during intercultural operations.
- Staking/supporting poles for fruiting branches to keep free from any insects, borer etc.

Mechanical approaches

- Inserting cotton soaked with kerosene and petroleum oil into the hole made by stem borer.
- Installing light traps in near apple orchard to collect insect pests.

Biological and botanical practices

- Treating FYM with *Trichoderma* 1.5 kg in 50 kg of FYM and applying fortified FYM compost to each matured tree foe minimizing root rot disease of apple.
- Using plant extracts or local materials like jhomal to suppress sucking insect pests.

Chemical approaches

- Applying Naphthalene Acetic acid (NAA) @ 10 ppm for fruit drops 2 weeks before fruit harvest.
- Using chemicals **blue and green labeled** only as the last option, if required.

Disease management

Apple scab

- Removing and destroying affected parts of fruit trees, because pathogen over winters in the infected leaves on the ground.
- Pruning overlapping branches for good sunlight penetration on fruiting spur, twigs and stem.
- Spraying 5% urea after fruit harvest and using fungicide, like Copper Oxychloride or Bordeaux mixture.
- Practicing biocontrol agent, like *Pseudomonas syringae* @ 1.5-2 g/l water.

Powdery mildew

- Wet spot in the fruit due to this disease deteriorates the quality market value.
- Collecting and destroying fallen pars, as immature fruit and leaf fall is common.
- Removing the infected twigs and branches.
- Using Copper Oxychloride, Bordeaux mixture, Sulphur dust and Karathene.

Papery bark

- The disease starts from main trunk, branches and twigs having wounds, then bark/ skin dry, crinkle and become leathery and feathery.
- Planting only healthy saplings.
- Applying Bordeaux paste immediately after pruning.

Insect pest management

Wooly aphids

- It is one of the serious pests in apple, the reddish purple color aphids covered with wool infest in mass in underside of the leaves on the terminal growth.
- Using of parasite, like *Aphelinus mali* for its biological control.
- Using coccinellid predators, which are useful in predating this pest.
- Spraying Servo @10-15ml / l of water or Neem based pesticide @ 3 ml/l water.
- Using systemic pesticide (only blue and green labeled) in severe case.

San Jose scale

- Using petroleum oil products, like Servo during dormancy period.
- Applying lime-Sulphur mixed with Servo oil.
- Spraying botanicals, like Neem oil @ 3 ml/liter of water and spray.
- Spraying Petroleum oil Servo oil @ 8-10 ml/liter of water.

Zygaena moth

- Encouraging use of spiders and earwigs that predate on it.
- Removing old apple, pear, walnut trees which may act as hosts for the pest.
- Spraying botanicals, like Neem oil @ 3 ml/liter of water.
- Spraying petroleum oil Servo oil @ 8-10 ml/liter of water.
- Using Bt.@ 2gm/l of water at 7 days interval.

Weed management

- Chemical herbicide not allowed.
- Encourage manual and mechanical weeding.
- Management the weeds on time (at least two times weeding is required).
- Proper disposal of weeds, or using as composting materials.

Harvest and post-harvest

- Harvesting at full maturity stage with appropriate TSS content and color (generally TSS should be at around 12-14^{o} B), and checking color of the seed to turn black.
- Avoiding damage to tree branches while harvesting, no bruises or injury to fruits.
- Using appropriate tools (clippers, knife, shear etc) to harvest fruits.
- Harvesting during day time in dry weather as far as possible.
- Preventing loss of moisture by surface evaporation, transpiration, and respiration resulting shriveling and weight loss, and storing in cool place not contacting harmful substances.
- Grading fruits on size and color categories (if the fruit size is 80mm or more extra-large, 75mm large, 70 mm medium, 65mm small).
- Packing in box best in size not bigger than 45cm x 30cm x 30cm size.
- Managing cushion materials in between the fruit in the pack.

3.6.4.2 Citrus (*Citrus spp.*)

Introduction

Citrus includes: Lime *Citrus aurantifolia* (Christm.) Swingle, Rough lemon *Citrus jambhiri* Lush., Indian sweet lime *Citrus limetttoides* Tanaka, Lemon *Citrus limon* (L.) Osbeck, Pumelo *Citrus grandis* (L.) Osbeck, Citron *Citrus medica* L., Grapefruit *Citrus paradisi* Macfad, Mandarin *Citrus reticulate* Blanco, Sweet orange *Citrus sinensis* Osbeck).

Citrus is leading tree fruit crop in the world. Mandarin (*Citrus reticulate* Blanco) is the excellent quality fruit with blend of acidity and sweetness enriched with vitamins and other nutritive values. It is the most important commercial fruit crop grown in the mid hills of Nepal. Of the total fruits with 26.3% coverage in the country, citrus fruit occupies 65.16% and mandarin is cultivated in area of 25123 ha with production and productivity of 149212 mt and 5.9 mt/ha, respectively (MOAD, 2018). Mandarin in mid hills is good source of income for the farmers and fruits have high export potential, which can earn foreign currency, and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance

1. Citrus farming is an important source of income for the mid hill farmers.
2. Citrus farming occupies an important place in fruit development in the country.
3. It is important fruit for health.
4. It is exportable fruit to foreign countries, which provide an opportunity for earning exchange.
5. Organic citrus farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

Fruit loss due to pest is major constraint of fruit growers. Devraj et al (2019) reported up to 100% loss of Junar fruits due to Chinese fruit fly in Sindhuli. Panth and Dhakal (2019) surveyed in Parbat district, which reveals 7.26 mt/ha productivity and price NRs.102.5 per kg of mandarin. The national production of fruit was 8.96 mt/ha, citrus 8.82 mt/ha and orange 9.2 mt/ha in 2014/15. There are many reasons for low productivity and yield gap in national/international contexts. The problems are associated with low productivity, are mainly due to farmers' traditional practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

The highest technological gap was found in intercrops, pest management, and seed treatment in India. Study also revealed that variables like Education, Extension participation, contact with extension agencies, innovative proneness and cosmopoliteness were found to be significant and negatively correlated with the technological gal of orange production technology (Yomgam et al., 2019).

Trifoliate orange seedlings are used as rootstock for citrus crops due to cold hardiness and Phytopthora disease tolerance, for which seeds sown in September inside plastic tunnel with open sides resulted 80% germination compared to 46% in tunnel side closed nursery in Dhankuta (Acharya and Pakka, 2019).

The challenge is to understand the interactions of the changing climatic parameters because of the interactions among temperature, CO2, and precipitation on plant growth and development and also on the biotic stresses of weeds, insects, and diseases. Agronomists will have to consider the variations in temperature and precipitation as part of the production system if they are to ensure the food security required by an ever increasing population (Hatfield et al., 2011)

Intercropping practices in orchard not only generate an extra income but the practice also helps to check the soil erosion through ground coverage and improves the physio-chemical properties of the soil. Intercropping in Kinnow orange orchard in Punjab has shown improved yield, fruit quality and economic aspect (Gill et al., 2018). Intercropping cucumber with citrus (mandarin) orchards improved the yields of citrus in India (Ouma and Jeruto, 2010). Intercroping in organic citrus orchards also suppressed weeds and thus improved the yield of citrus fruit (Linares et al., 2008).

More than 170 species of invertebrate natural enemies are produced and sold worldwide for use in augmentative biological control of more than 100 pest species (Cock et al. 2010). Benefit/cost ratio and the developmental costs are much more favorable for biological control than for chemical control (Bale et al., 2009; van Lenteren, 2011).

While evaluating 3 pest management modules (bio-intensive, IPM and farmer practices) in citrus orchard, IPM was the best one with higher net returns (3.95 B: C ratio over control) in North India (Deka et al., 2018). So, Integrated Pest Management strategy, based on the reduction of insecticide treatments and the use of selective insecticides and moreover augmentative, periodic releases of bio-agents to maintain the pest populations below economic damage limits.

Agriculture Policy of the European Union, is providing a good enabling environment for agriculture innovation and knowledge is transferred from innovation to farmers rapidly.

Production practices need to follow step-by-step from the beginning to end of citrus production cycle to ensure healthy production and higher productivity, and farmers are not following properly, i.e., why they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice
1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Orchard health	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Training/pruning	Training/pruning to assure healthy orchard	Not following properly
4	Optimum soil pH	Lime application @ 5-7 kg/tree to correct acidic soil	Not following correctly
5	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
6	Micronutrient use	Based on soil analysis micronutrient use	Not following properly
7	Irrigation	Critical at veg growth, flower, fruiting stage	No facility or not following
8	Intercropping	Short duration legume crops, vegetables	No intercrop or other than legume crops
9	Pollinators conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of citrus flowers
10	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
11	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality fruits	Poor care during harvest/ postharvest

Citrus farmers groups

Three citrus farmers groups organized in the project district Gulmi and oriented them in IPM-FFS for production and management of citrus especially orange:

- Planning for IPPM technology based citrus orchards.
- Keeping prior history and yield of citrus.

- Recording soil test, pH, OM, NPK.
- Selecting orchard and variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Nursery/ Orchard management

- Establishing citrus nursery at 1000m and above from sea level for sapling production.
- Keeping nursery site & soil free from insect pests and diseases.
- Well drained soil, in clay soil 1:1:1 soil, sand and FYM mixed for maintaining quality saplings.
- Using rootstock Trifoliate or sour orange are used and for grafting mother plant should be healthy, productive and free from any graft transmissible diseases.
- Buying planting materials from reliable source/registered nursery.
- Maintaining appropriate planting distance (P-P 6m x 6m) in orange orchard.
- Preparing pit $1m^3$ size for planting of good quality sapling.
- Planting and maintaining windbreak trees around the orchard.
- Growing legume crops as intercropping to improve soil fertility, trap crops for insect pests and cover crops for moisture retention.

Manure and fertilizers

- Using balanced nutrients, a ten years mature orange tree requires 40 kg FYM and 300-500:200-250:250-350 gms NPK per tree.
- The final dose of manure / fertilizer is decided as per the soil test result.
- Applying manure and fertilizer in the basin, FYM well before the initiation of the new growth / flowering; 50% of the annual requirement of N and total P and K applying in Feb- March, usually 15 days before flowering and remaining 50% during the fruit enlargement period.
- Applying micronutrients Znso4:2.5kg, Cuso4 1.5, $MgSo_4$:1Kg, MnSo4:1kg FeSo4:1kg Boric acid: 1kg Slaked Lime: 1kg urea 4.5kg water 450 lit per ha, which is based on plant growth and soil test.

Intercultural operation and irrigation

- Keeping basin area around the tree weed free with manual weeding and shallow hoeing.
- Avoiding injuries to roots/collar of trees during interculture and disposing dropped fruits properly.
- Intercropping legumes and seasonal vegetables, like green peas, beans, broad leaf mustard crops.
- Mulching with straw, dust, rice husk, and wood dust especially during summer season to prevent weeds and moisture conservation.
- Irrigating citrus orchard in ring basin system after each fertilizer application and peak demand of water for the tree is during Feb-May. Forth-nightly irrigation is useful during flowering and fruit setting time.
- Drip/sprinkler irrigation system is appropriate for citrus in hills.

Training/Pruning

- Removing water shoots, unwanted and overlapping and disease twigs and branches of fruiting trees.

- Training/pruning of orchard considering the flowering and vegetative, buds space, nutrient, light and air.
- Applying Bordeaux paste on the cut surface after pruning and de-suckering from rootstocks.

Pest management

- Weekly monitoring as survey and surveillance to maintain the record of the pests.
- Promoting conservation of natural enemies by augmentation and inundation.

Cultural practices

- Practicing citrus orchard sanitation.
- Irrigating timely for managing soil insects in the orchard.
- Using pest repellent flowers, like marigold, chrysanthemum depending upon the suitability around the orchard.
- Applying Bordeaux paste or other indigenous materials to cover cut/wounds.
- Avoiding injuries to roots or collar of trees during intercultural operations.
- Staking/supporting poles for fruiting branches to keep free from any insects, borer etc.

Mechanical approaches

- Inserting cotton soaked with kerosene and petroleum oil into the hole made by stem borer.
- Installing light traps in near citrus orchard to collect insect pests.

Biological and botanical practices

- Treating FYM with *Trichoderma* 1.5 kg in 50 kg of FYM and applying fortified FYM compost to each matured tree foe minimizing root rot disease.
- Using plant extracts or local materials like jhomal to suppress sucking insect pests.

Chemical approaches

- Applying Naphthalene Acetic acid (NAA) @ 10 ppm for fruit drops 2 weeks before fruit harvest.
- Using chemicals **blue and green labeled** only as the last option, if required.

Disease management

HLB

- Removing and destroying of infected plants and alternate hosts or control vector in these host.
- Using sapling from registered nursery maintained above 1000masl.
- Pruning overlapping branches for good sunlight penetration on fruiting spur, twigs and stem.
- Controlling the disease vectors (Citrus psylla (*Diaphornia citri*), with systemic insecticide (blue/green label).

Phythopthora rot

- Use resistant rootstocks grafted saplings in new orchard.
- Drench/paste/foliar spray the infected trees with 1% Bordeaux mixture.
- Paste twice a year (before and after the monsoon rains).

Citrus tristeza

- Using the plants grafted in tolerant rootstocks and clean grafting tools in the orchard.

- Rouging of infected plants by uprooting and burning them.
- Controlling virus vector black aphids and conserving its predators and parasites.

Citrus canker

- Removing and destroying of affected twigs or branches of tree.
- Using of copper fungicide, 1% Bordeaux mixture or Copper Oxychloride 50% WP @3gm/liter of water in combination with Streptomycin 500 ppm.

Powdery mildew

- Following timely training/pruning to remove overcrowded branches and twigs.
- Removing the infected twigs and branches and destroying them properly.
- Spraying fermented urine helps to minimize the disease.
- Using Wettable Sulphur 2 gm/liter of water and Copper Oxychloride 4 gm/liter of water.

Insect pest management

Citrus psylla

- Conserving predators like ladybeetles, syrphid flies.
- Uprooting and burning infected plants, and destroying alternative hosts.
- Spraying with blue /green labeled insecticides-Neem oil, servo oil.

Citrus leaf miner

- Fertilizing during the winter and pruning infected flushes.
- Using Neem cake soaked in water and spraying Neem oil 2-3 ml/liter of water.
- As last resort spray with blue/green labeled chemical pesticide.

Citrus aphids

- Conserving predators and parasites of parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.
- Using systemic pesticide (only blue and green labeled) in severe case.

Citrus mealybugs

- Conserving predators and parasites of parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.
- Using pheromone traps- Sex Pheromene- Planococcyl acetate.

Citrus scales

- Conserving predators and parasitoids for its biological control.
- Removing and burning infested fruits/ or twigs/ leaves.
- Removing and burning infested fruits/ or twigs/ leaves.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.

Citrus thrips

- Conserving predators and parasitoids for its biological control.
- Spraying Neem oil or Servo oil @ 2-3ml / l of water.

Citrus green stink bug

- Hand picking of eggs, nymphs and adults and destroying them.
- Maintaining orchard sanitation and spraying de-moulting hormone (applaud).

Citrus fruit fly

- Collecting infested fruits and burning or feeding to animal.
- Disturbing tree basin soil frequently to expose pupae and predating by birds.
- Using pheromone traps with recommended poison baits.
- Treating soil under the tree with insecticide (green/blue label).
- Practicing area-wide control with spot treatment weekly starting week before flowering till fruit mature.

Harvest and post-harvest

- Harvesting at full maturity stage during day time with appropriate TSS content and color (Yellow-orange color by> 65-70 %).
- Avoiding damage to trees while harvesting using appropriate tools (clippers, knife, shear etc).
- Collecting harvested fruits on specified trays or baskets to prevent damage.
- Storing in cool place, preventing loss of moisture through surface evaporation, transpiration, and respiration resulting shriveling and weight loss.
- Preventing loss of moisture by surface evaporation, transpiration, and respiration resulting shriveling and weight loss, and storing in cool place not contacting harmful substances.
- Avoiding use of any chemical for aroma, outlook, brightness of crop.

3.6.4.3 Rapeseed (*Brassica* spp)

Introduction

Rapeseed is one of the most important cruciferous oilseed crops in the world. The commonly grown oilseed crops in Nepal are: rapeseed *Brassica campestris var. toria* L., mustard *Brassica campestris var. juncea* L., and yellow rapeseed *Brassica campestris var. sarsoo* L., Among them, rapeseed (tori) is the major oil extracting crop in Nepal. It occupies about 85% of the oilseed crops in Nepal. Rapeseed and mustard seeds contain 40-45% oil and 24% protein respectively, which are considered safe for people with weak heart and suffering from chronic diseases. It is cultivated in area of 173,228 ha with production and productivity of 182,917 mt and 1.1 mt/ha, respectively (MOALD. 2018). Rapeseed in terai and mid hills is good source of income for the farmers and its oil has high export potential, which can earn foreign currency, and reduce reliance on foreign import as well. In spite of its high significance there are many constraints faced by the farmers in Nepal, which requires due attention.

Importance

1. Rapeseed farming is an important source of income for the farmers.
2. It occupies an important place in oilseed production in the country.
3. It is safe for people with weak heart and suffering from chronic diseases.

4. It is exportable to foreign countries, which provide an opportunity for earning exchange.

5. Organic farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators and is best suited for eco-farming.

Farmers' practices and production gaps

According to Kumar (2017) loss in seed yield due to mustard aphid and cabbage caterpillar infestation varied from 18.3 to 24.5% and major insect pests were mustard aphid and cabbage caterpillar in Ludhiana, India, productivity of rapeseed is less than one mt/ha in the national context. This productivity is very low and many problems are associated with low productivity, mainly due to farmers' traditional practices. Major contributing factors are: favorable weather, soil fertility and balanced use of fertilizers, irrigation facility, proper cropping practices, pollinators' management, bio-rational management of pests and Agriculture Policy enabling good environment for agriculture and innovation.

From organized studies during the last ten years on rapeseed-mustard in India, the average productivity gap of 10 to 25% is estimated between the improved and farmers' practices. The production is only 28, 44 and 54% of EU, Canada and China productivity, respectively (Sharma et al., 2018). The yield of rapeseed-mustard in improved practices under irrigated conditions ranges from 15.89 to 1.86 mt/ha and in farmer's practice between 1.25 to 1.4 mt/ha. The increase in yield with improved over farmer practice recorded in the range of 26.82 to 33.14% in India (Meena et al., 2012).

The aphid population differs significantly among variety and weathers parameters. Prasad (1983) evaluated the relative susceptibility of 20 cultivars of sarson, 30 cultivars of brown sarson and 40 cultivars of rai (*Indian mustard*) to infestation of *L. erysimi* in field trial in Delhi, India. The minimum mean aphid infestation was recorded in mustard cultivar IB- 680 and maximum in yellow sarson variety IB-787, respectively.

Intercropping mustard + coriander also reduced aphid infestation by 60.3% over control, which was better than Thiamethoxam chemical treatmentin in UP, India (Reddy et al., 2018). Intercropping combinations also showed positive and significant ($P \leq 0.01$) effect on water capture efficiency compared with sole cropping treatments (Koocheki et al., 2014).

Balanced nutrient is important for maximizing potential production of brassica. Ara et al. (2014) obtained the highest seed weight per plant, 1000 seed weight and oil content percent of rapeseed at 120kg Nitrogen/ha and 2 kg Boron /ha in Bangladesh.

Honey bee visitation to the brassica flowers is important for pollination and increasing seed yield. Among the three brassica crops tested in Almora, a greater number of bees were found visiting broccoli under net house condition (6.05 bees/plant) with the highest net benefits followed by kohlrabi (5.35bees/plants) and Chinese cabbage (5.05 bees/plant), respectively (Sushil et al., 2013). The seed weight and yield (gm) with pollination was 26 and 7.6 (gm) and without pollination was 9.3 and 1.51 (gm), respectively in Pakistan (Munawar et al., 2009). Chandel et al (2000) compared the performance of two honey bee species and reported that A. cerana collected more nectar load (mean 13.8mg) than A. mellifera (mean 12.1mg) from torai in Himanchal Predesh, India. *A. mellifera* visits on the blooms of *B. napus* and *B. juncea* resulted in the highest seed weight per pod (106.09 and 98.58 mg, respectively), On *B. napus, A. mellifera* pollination resulted in 127.14, 23.69 and 49.65% increase in the number of pods per plant, number of seeds per pod and seed yield over exclusion of pollinators, while on *B. juncea*, the corresponding figures were 83.78, 35.39 and 43.46%, respectively in India (Kumari, 2014). Kevan and Eisikowitch (1988) reported that presence of pollinators, i.e. honey bees, on canola (cv. 0.A.C Triton) increases the germinability of resulting seeds from 83% to 96%, while pollination excluded seeds from bees germinate less than 83%. In Brazil, two cultivars self-compatible, but free visitation of insects tested increased productivity by 17% in the Hyola 420 cultivar and by approximately 30% in the Hyola 61 cultivar (Blochtein et al., 2014).

Among the several natural enemies in brassica field, few are very common, i.e., coccinellids, *Coccinella septumpunctata* L.; Syrphid fly, *Ischiodon scutellaris* F. and *Diaeretiella rapae* MacIntosh. Among the 7 insecticides (Imidacloprid, Thiamethoxam, Clothianidin, Thiaclorprid, Flonicamid, Dinotefuran, and Dimethoate) tested, thiamethoxam 25 WG, 0.01%recorded higher activity and proved comparatively safer to natural enemies and honey bees (Chaudhary et al., 2016).

Insect-resistant GM cultivars of oilseed rape are also being developed. For example, plants are being modified to contain *Bt* toxins and proteinase inhibitors (PIs), and these have potential to reduce insecticide application (Alford, 2003).

The economic yield of C_3 plants at elevated CO_2 can involve larger seed or grain size, more seeds/pod, ear or panicle, and/or more reproductive structures per plant, and C4 plants can’t benefit. However, all C3 oilseed and grain crops had a lower harvest index at elevated CO_2. Franzaring et al. (2008) reported 18% economic yield, 18% individual seed weight and 17% above ground biomass increase of oilseed rape at elevated CO_2.

Considering human health and environmental pollution and pest resistance, for their management early sowing, yellow sticky traps, bio-agent conservation and application of safer chemical insecticides has been recommended.

Production practices need to follow step-by-step from the beginning to end of rapeseed production cycle to ensure healthy production and higher productivity; farmers are not following properly, so they are not getting higher yield.

SN	Production practice	Ideal practice	Farmers practice
1	Soil testing	Periodic soil analysis for nutrient status	Nutrient status unknown
2	Field hygiene	Timely cleaning, weeding, ploughing	Unhealthy orchards
3	Optimum soil pH	Lime application to correct acidic soil	Not following correctly
4	Balanced nutrient	Based on soil analysis optimum dose use	Not following properly
5	Micronutrient S use	Based on soil analysis micronutrient S use	Not following properly
6	Irrigation	Critical at veg growth, flowering stage	No facility or not following
7	Pollinators use and conservation	Conservation and use of pollinators (bees) to assure good pollination and fruit setting	Unknown about pollinators of rapeseed flowers

8	Pest management	Biorational and ecofriendly pest management	Indiscriminate use of pesticides
9	Harvest/postharvest	Proper care at harvest and after harvest for maintaining quality seeds	Poor care during harvest/ postharvest

Rapeseed farmers groups

Three farmers groups organized in the project district Dang oriented in IPPM-FFS for production and management of Brassica especially rapeseed:

- Planning for IPM technology based rapeseed production.
- Keeping prior history and yield of rapeseed.
- Recording soil test, pH, OM, NPK.
- Selecting farmer's field and rapeseed variety with managed irrigation and drainage facility.
- Recording temperature, rainfall, especially during flowering & fruiting period.

Field preparation and sowing

- Farmer's field drained fertile sandy loam to clay loam soil with 6-8 pH.
- Ploughing and preparing field for FFS conduction and learning by farmers groups in their local situation.
- Selectiung varieties- Moran Tori-2, Preeti, Unnati, Pragati, Bikash, T-9, JY-16.F1 etc.
- Treating seeds with 2.5-3 gm fungicide for blight & rot.
- Planting in rows 30 cm apart with plant-plant distance of 10-15 cm

Manure and fertilizers

- Using well decomposed FYM 10 mt/ha 20-25 days before seed sowing.
- Using chemical fertilizers @ 60: 40: 20 kg NPK/ha, half dose of N and full dose of PK as basal, and remaining N after 20-25 days with first irrigation.
- Using sulfur 20 (Sulfur dust) and boron 10 (Borex) per ha, and if soil deficient in zinc adding 10 kg zinc sulfate is recommended.

Intercultural operation and irrigation

- Thinning of rapeseed field to maintain uniform plant population and removing of weeds simultaneously.
- Manually weeding Orobanke in the rapeseed field and destroying properly.
- Irrigating field with first light irrigation at 25 days and another at 55 days.
- Introducing lentil as intercropping or two row rapeseed and one row lintel is beneficial.

Diseases management

Alternaria blight

- Using tolerant variety of rapeseeds.
- Adopting timely sowing of seeds,10-25 October.
- Removing weeds particularly collateral host plants.
- Applying recommended dose of potash to reduce disease incidence.
- Using *Trichoderma harzanium, T. virens, Streptomyces arabicus* as biocontrol.

- Spraying before flowering Metalaxyl 8% + mancozeb 64% WP @1500 g in 600 l of water/ha as last resort.

White rust

- Following timely sowing of rapeseed and following rotation.
- Removing and destroying crop debris particularly stag heads of previous year crop.
- Avoiding over irrigation or water stagnation in the field.
- Using *Penicillium citrinum, Aspergillus ochraceous, Bacillus subtilis, Pseudomonas fluroscens etc* as biocontrol.
- Using Metalaxyl 35% WS @ 0.75- 1.0 kg/100 kg seed treatment before sowing.

Downy mildew

- Following long crop rotation with cereals and adopting proper field sanitation.
- Avoiding over irrigation or water stagnation.
- Applying potash at recommended dose.
- Using *Penicillium chrysogenum, Trichoderma viridi* as biocontrol.
- Spraying carbandazim 0.1% or mancozeb 0.25% as last resort.

Powdery mildew

- Adopt proper field sanitation and destroying crop infected and residues.
- Applying potash at recommended dose.
- Using fungal hyperparasite, *Ampelomyces quisqualis* as biocontrol.
- Spraying just before initiation of flowering with wettable sulphur 0.02% or carbandazim 0.03% and repeating at 10-14 days intervals taking care of considering pollinators.

Insect pest management

Mustard aphid

- Early sowing to scape and avoid damage.
- Using yellow sticky traps for attracting and trapping aphids.
- Using 2% Neem oil or 5% Neem Seed Kernel Extract (NSKE).
- Conserving prasitoids *Aphelinus,* predators ladybird beetle, lacewing, syrphid flies.
- Using Entomopathogenic fungus *Cephalosporium and Verticillium.*

Painted bug

- Deep ploughing the soil to destroy eggs of painted bug.
- Early sowing to avoid pest attack.
- Conserving bio-agents *Alophora spp.* (tachinid fly) that parasitize eggs of painted bugs.
- Spraying dichlorvos76% EC @ 350 ml in 300-500 l of water/ha taking care of pollinators.

Mustard saw fly

- Summer ploughing to destroy the pupae and early sowing to scape damage.
- Collecting and destroying larvae of saw fly in morning and evening hours.
- Conserving *Perilissus* and *Serratia species* that infect the larvae of sawfly.

- Spraying dimethoate 30% EC @350 ml in 300-500 l of water/ha taking care of pollinator.

Harvest and post-harvest

- Harvesting usually in the morning at maturity stage, i.e. 75% pods turning yellowish color.
- Uprooting or using appropriate tools sickle to harvest crops.
- Drying 3-4 days on sunshine and then separating seeds by beating against hard wood or flat stone.
- Cleaning and drying seeds on sunshine and storing at 8-9% moisture.

CHAPTER 4

Activity-3: Field survey, sampling and preservation of the collected samples

(Study of the arthropods and pollinators in project districts)

4.1 Introduction

Increasing population demand for higher amount of food led to increased competition for farmland, land-use change, habitat fragmentation, changes in crop rotations and biodiversity losses (Rulli et al., 2016). The agriculture land use practices affect large number of terrestrial organisms and is the main drivers of the biodiversity loss (Habel et al., 2019). The loss of the farmland biodiversity alters species interactions which lead to decline in ecosystem functions and ecosystem services (MEA, 2005). The current practices of the agriculture land use change will continue to pose the threat on the biodiversity and ecosystem services (Veerkamp et al., 2020). The agricultural biodiversity is critical to ensure the long-term resilience which is associated with ecosystem services and functions (Tscharntke et al., 2012).

Insect diversity and abundance all over the world are declining (Hallman et al., 2017). For the maintenance of diverse agroecosystem, insect diversity and abundance play the important role among which arthropods are the dominant terrestrial groups (Zhang, 2011). Beyond being a conservation concern, insects provide important ecosystem services. Within agriculture, biological control and pollination services provided by insect natural enemies and wild bees were estimated to be worth over $7.5 billion in the US (Losey and Vaughn, 2006) and 35% of total crop production worldwide depends on pollinators (Klein et al., 2007). The loss of the natural habitat and the agricultural intensification causes the decreases in the agroecosystem services such as biological control of pest and pollinators and reductions of the foraging and nesting habitat (Biesmeijer et al., 2006; Potts et al., 2010; Garibaldi et al., 2016).

Mustard **(***Brassica campestris* Var. toria**)** is a mass flowering oilseed crop belongs to the family Brassicaceae (or Cruciferae) with the total area under cultivation in Nepal was 260,307 ha with the production of 280,530 mt with the average productivity of 1,078 kg/ha (MOAD, 2018). Various types of arthropods such as insect and spider species are found in the mustard field as they get shelter, food and oviposition site. Many of the insects and spiders have profound effect as pest, predator or pollinator and some of them just prevail in the field. Pollinators aid in pollination as well as fruit setting (Devkota et al., 2021). Beneficial insects like predators, parasitoids and other arthropods maintain an ecological equilibrium. With the aims to identify the major pollinators and arthropods in the mustard crops, the research was carried out in the three research areas of the Dang district, Nepal.

4.2 Methodology

Study location

Fieldwork was carried out in 2019 on the mass flowering crop mustard (*Brassica campestris* var. toria: Brassicaceae) in the Dang district, Citrus in Gulmi distircts and Apple (*Malus domestica)* in Mustang district of Nepal. We selected commercially growing areas of mustard, citrus and Apple crop in the during the blossom period in three sites in the respective districts. Since we sampled in three localities × three repetitions in each mustard crops, we obtained 9 sampling units. In case of citrus and apple we carried out the sampling in the two different pratices i.e Agroecosystem Pracitces and Farmers practices. Here the agroecosystem pratices is the practices where FYM is fortified, use of tichoderma, azotobacter and biological pest controls were carried out but farmers practices where there is no use of FYM and other biological pest control was carried out in the three research sites, consisting 36 samping units. The each practices were at least 50 m far apart fo the pollination and soil arthopdos study. At each sites described above, we established a quadrat of 1,250 m^2 (50 m × 25 m) for sampling flower-visiting insects following a protocol to detect and assess pollination deficits in crops as suggested by the Food and Agriculture Organization of the United Nations (Vaissière et al., 2011).

Insect sampling

Sampling began when more than 10% of the mustard crop began to bloom. In each quadrat, we sampled all insects visiting the mustard crops. The pan traps methods is widely used in the survey of the pollinators in the different plant and crops (Westphal et al., 2003; Grundel et al., 2010). We arranged pan traps in a sequential along the 150 m^2 transect on each oilseed and buckwheat crops in the study area. Pan traps were arranged along a transect in a linear manner, containing 3 pan traps of yellow, blue and white color being randomly placed in each transect of 25 m, spaced a minimum of 5 m apart (Droege, 2010). Altogether six groups consisting 18 pan traps, of three colors yellow, blue and white were adjusted in the study area comprising six color of each in the six transect of study area as protocol suggested by the Canadian pollinator initiative. We filled each pan trap with soapy water to break the water tension placed on the ground itself as the broader scope of research to investigate the pollinator's diversity in the flooded and non-flooded areas (Abrahamczyk et al., 2010), remained exposed for 24 hrs per sampling (Westphal et al., 2008). Consequently, to quantify how many insects visited the target crop, we measured by scan sampling a fixed number of open floral units in each experimental unit. The five hundred flowers or flowering units of mustard crops were assessed by scan sampling, as there was no duration attached to the observations; rather, an insect will be recorded or not depending on whether it is present at the time a given flower is first seen, which is the most reliable way to assess the abundance of insects that reside on flowers (Levin et al., 1968; Westphal et al., 2008). The scan sampling was performed by walking slowly along each transect line and recording the numbers of flower-visiting insects seen when looking at the individual floral units one by one in sequence (Vaissière et al., 2011). Insects captured with the aerial nets were pinned, labelled and subsequently identified to the genus and species level in the entomology laboratory of the Agriculture and Forestry University in Nepal.

Predators and parasites sampling

A total of the four quadrant of 1*1 m^2 was established within the 50m * 25m areas plot on each site to assess the study of the predators and parasites on the mustard crops in the three research sites. The study was carried in weekly internal after the onset of the flower in the mustard. The major predators and parasites namely, lady bird beetle, ground beetle, syrphid flies, tiger beetle, tachinid flies, spider, mustard sawfly, ants, wasps, earthworm and painted bug was assessed.

4.3 Data analysis

Average number of pollinators and arthropods

The average number of pollinators and arthropods registered in each research site was plotted, here, as the mean number of pollinators and arthropods using as a measure of dispersion the confidence intervals at 95%. This approach is an accurate method to infer statistical significance once different intervals do not overlapping each other (Sim and Reid, 1999).

Biodiversity analysis

The number of unobserved species was estimated using the function (Chao et al., 2014) using the ‘specpool’ function of the *vegan* package (Oksanen et al., 2018). Afterward, we evaluated whether our sampling effort was enough to show the pollinator and arthropod richness. As such, we performed a rarefaction curve of the pollinator and arthropod species by calculating interpolation/extrapolation according to the number of individuals sampled.

On the other hand, we performed a diversity profile with a diversity order of Hill’s series (Hill 1973). The diversity profile allows us to dynamically compare the diversity of any organism between different communities along the parameters at the scale (Rényi’s diversity) (Chao et al., 2014). Therefore, if all the values in such scale were the greatest in a specific community, it can be considered the most diverse among all other analysed (Tóthmérész, 1995). Such an analysis was carried out by splitting the diversity matrix from each research site and posteriorly using the ‘renyi’ function (hill=TRUE) of the *vegan* package (Oksanen et al., 2018). Yet, sampling effort was estimated, and plotted, by rarefying and extrapolating samples along each research site using the *iNEXT* and *ggiNEXT* functions from homonym package (Hsieh et al., 2018).

To investigate the community composition of pollinators among three research sites (Bagmare, Ragaicha, Saunepani) we performed a non-metric multidimensional scaling (NMDS) analysis. As a result, our dataset was standardized by the ‘rank’ method. It implies in replacing the abundance values for their respective relative ranking and leaves zero values unaltered. Next, this dataset was converted into a dissimilarity matrix with Gower’s method. This method divides all distances by the number of observations (rows) and scales each column to the reach unit. In this way. Therefore, the NMDS was carried out using the ‘metaMDS’ function of the *vegan* package, which the *stress* value was used to evaluate the ordination quality. Posteriori, the composition of the pollinator and arthropod community was tested with an ANOVA with permutations (PERMANOVA, 1,999 randomizations) controlling for sample location with the ‘adonis’ function of the *RVAideMemoire* package (Hervé, 2020).

Finally, we performed a hierarchical clustering applying the unweighted pair group method with arithmetic mean (UPGMA), the same as average linkage, using the Euclidean method as a measure distance (rows, columns). UPGMA captures the average distance between each point in one cluster to every point in the other cluster. This data exploring was plotted as clustered heatmaps using the ‘pheatmap’ package (Kolde, 2019). Since numbers of sampled organisms in each sampling unit drastically differ among them, such values were centered and scaled in the row direction. Posteriori, we used the ‘cophenetic’ and ‘cor’ functions from the *stats* R package to carry out the cophenetic correlation index, a way to evaluate the level of goodness-of-fit of the resulting dendrograms. All analyses were performed in R-statics (Ihaka & Gentleman, 1996; R Core Team, 2020).

4.4 Results

Mustard crops

Overall, we collected 427 specimens of pollinators being identified 17 pollinator taxa in our work. However, our findings suggest that the expected number of pollinator taxa should be something like 29.45 (± 28 s.d.). Three pollinator taxa showed upmost means: *Megachile* spp., *Halictus* spp., and *Andrena* spp. (Figure 7A). The diversity profile indicates that Ragaicha site had a highest richness (Figure 1B). Nevertheless, the pollinator community on such locality is smaller as we go to right side of scale when the abundance of organisms possesses more importance (Figure 7B). However, our rarefaction curves indicates that in Ragaicha and Saunepani sites exhibited similar behavior in diversity profile, most likely have more pollinator taxa to be observed if the number of individuals was higher than that sampled here (Figure 1C). Yet, the NMDS had a stress value of 0.06, suggesting an enough ordination fitting. However, even though three research sites seem to present different pollinator community, they somewhat overlap each other and are near to origin [0,0]. As such, our PERMANOVA test showed that, overall, they are similar in three research sites (Table 1). It can be an artifact since, at least, Ragaicha and Saunepani should have more (exclusive) pollinator taxa to be found (Figure 7).

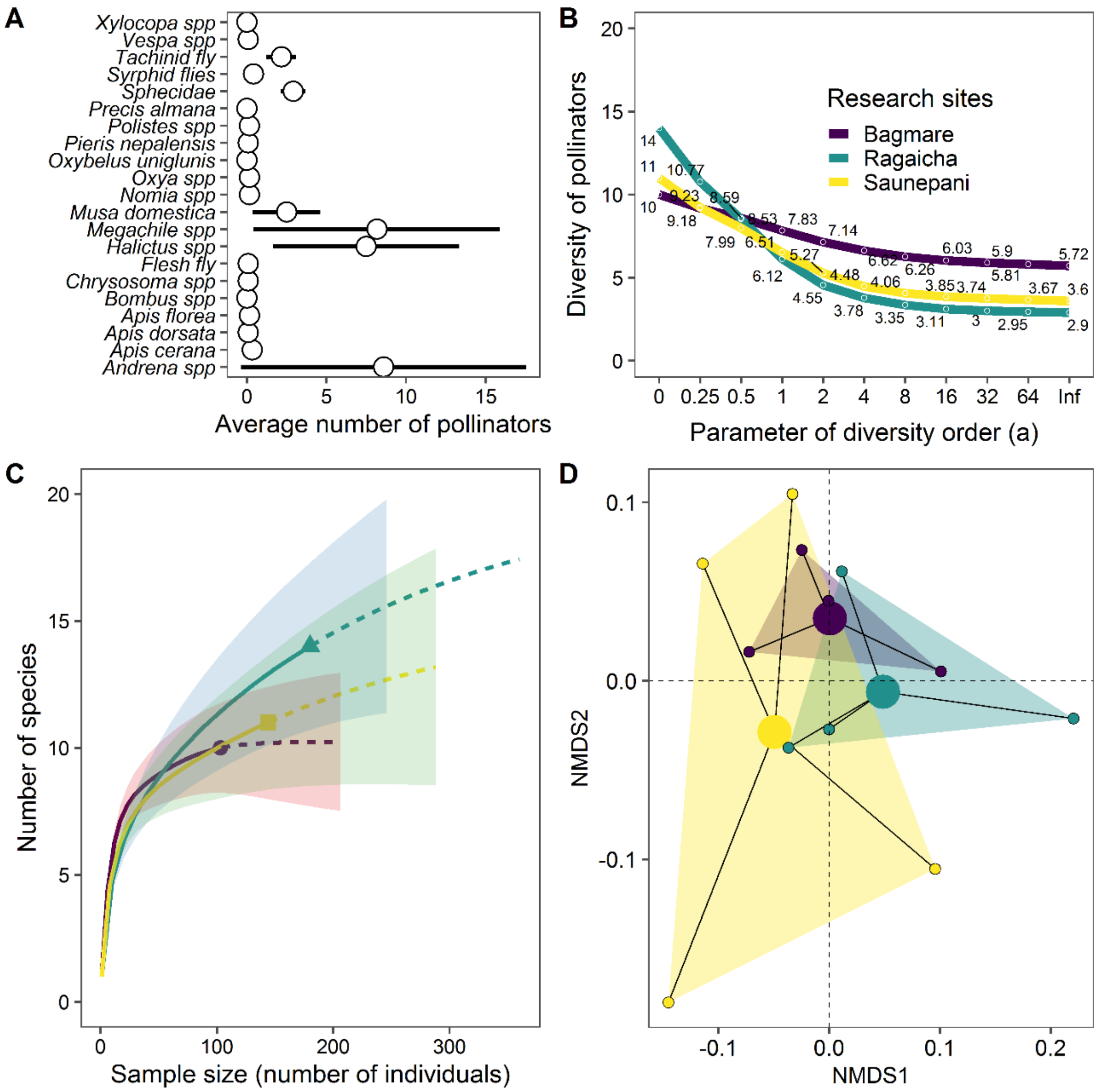


Figure 7. Pollinator dicversity (A) and diversity profile of the Hill´s series (B)

Pollinator diversity (A) Average number of pollinators by joying all three research sites (Bagmare, Ragaicha, Saunepani). The points indicate the mean, while horizontal black lines exhibit the confidence intervals at 95%. **(B)** Diversity profile of the Hill´s series. The *x*-axis displays the change in diversity over the parameter scale; the *y*-axis shows the level of diversity for measures on the *x*-axis. The left-hand side of the *x*-axis is more sensitive to rare species, whereas the right-hand side is more sensitive to the abundance of pollinator taxa. This continuum of values allows inferring the contributions of rare vs. abundant species in a community. Inferred diversity indices can be retrieved from such a parameter scale as: 0 = species richness; 1 = Shannon-Wiener index; 2 = Simpson index; inf = Berger-Parker index. **(C)** Rarefaction curves of pollinator taxa: *x*-axis – number of individuals per sampling unit; *y*-axis – interpolation (solid line) and extrapolation (dashed line) estimating the expected number of putative taxa to be seen; the shadow indicates the confidence intervals (95%); **(D)** Non-metric multidimensional scaling (stress = 0.06) showing the community composition of pollinators. In D, the larger points mean the centroids, while the smaller points represent the sampling units. Note: Colors in B-D panels should be interpreted as seen in legend of the B panel.

Table 19. PERMANOVA parameters and subsequent paired comparison of the composition of the pollinator community associated with research sites, Nepal

	Degrees of freedom	Sum of squares	Mean squares	F	R^2	*p*-value
Research sites	2	0.06	0.03	0.89	0.16	0.68
Residuals	9	0.30	0.03		0.83	
Total	11	0.37			1.00	

In predators and parasites study, we collected 299 specimens of arthropods in which seven groups were identified. It appears to be an enough quantity since the expected number of was equal to seven without measure of dispersion. The two more abundant groups of arthropods were Ladybird beetles followed by Mustard saw flies (Figure 8A). The diversity profile indicates the three research sites Bagmare, Ragaicha and Saunepani showed as similar arthropod community regardless of rare (left side) or abundance (right side) of organisms receive more or less importance (Figure 8B). In the rarefaction curves, it is possible to infer that all three sites had a similar behavior displaying an enough richness when less than 50 specimens are sampled (Figure 8C). The stress value of such NMDS was of 0.15, also indicating an enough ordination fitting. Moreover, and corroborating the Figures 2B-C, the arthropod community among three research sites were sufficiently overlapped each other and are again near to origin [0,0] (Figure 8D). Consequently, the PERMANOVA test showed that there is no statistical difference among all three localities concerning to arthropod fauna (Table 2).

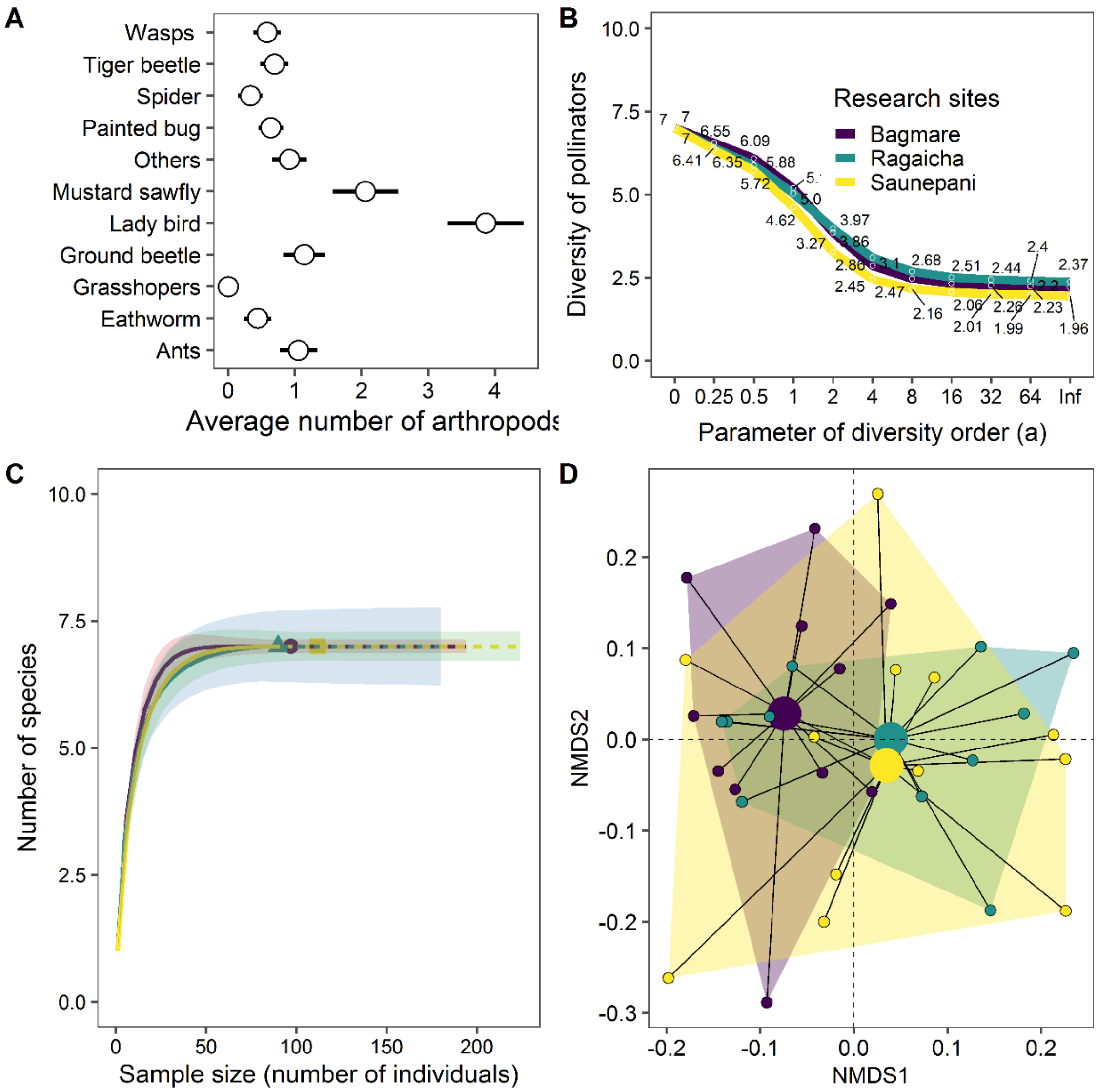


Figure 8. Comparison of trophic niche width (Shannon-Wiener index, H')

Figure 8 Comparison of trophic niche width (Shannon-Wiener index, H′) between non-eusocial and eusocial bees after phylogenetic generalized least squares (PGLS). Note: white points indicates the mean (H´ eusocial = 2.54, H´ non-eusocial = 1.37); vertical black lines show the confidence intervals (95%); horizontal red dashed line exhibits the overall mean (H´ = 2.09) combining all bee taxa. (A) Rarefaction curves of mite species: *x*-axis – number of individuals per sampling unit; *y*-axis – interpolation (before value) and extrapolation (after value) of the Hill number with order q = 0 exhibiting the species richness found and the number of expected species against the average. The shadow indicates the confidence intervals (95%); (B) Diversity profile of the Hill numbers. The *x*-axis shows the change in diversity indices over the Hill numbers; the *y*-axis displays the level of diversity for measures on the *x*-axis. The left-hand side of the *x*-axis is more sensitive to rare species, whereas the right-hand side is more sensitive to the abundance of insect taxa. This continuum of values allows inferring the contributions of rare vs. abundant species in a community. Some diversity indices on the *x*-axis can be inferred: 0 = species richness; 1 = Shannon-Wiener index; 2 = Simpson index; inf = Berger-Parker index; (C) Number of mites sampled according to stingless bee species. Note: The total number of mites was transformed into the square root to facilitate visualization. The approximate value in the x-axis can be retrieved with the square power. (D) Non-metric multidimensional scaling (stress = 0.05): Community composition of mites sampled according to stingless bee species. Note: Larger points are the centroids; smaller points are the sampling units. Colours in all panels represent the stingless bee host (see legend in B). The full species names are listed in earlier text document.

Table 20. PERMANOVA parameters and subsequent paired comparison of the composition of the arthropod community associated with research sites, Nepal.

	Degrees of freedom	Sum of squares	Mean squares	F	R^2	*p*-value
Research sites	2	0.09	0.04	1.19	0.06	0.27
Residuals	33	1.36	0.04		0.93	
Total	35	1.45			1.00	

The hierarchical clusters of pollinator and arthropod communities mirror the diversity analyses described above (overlapping, no community difference) since sampling units from different research sites often grouped together or nearer each other than all sampling units belonging to same and concerning research sites (Figure 9 A-B).

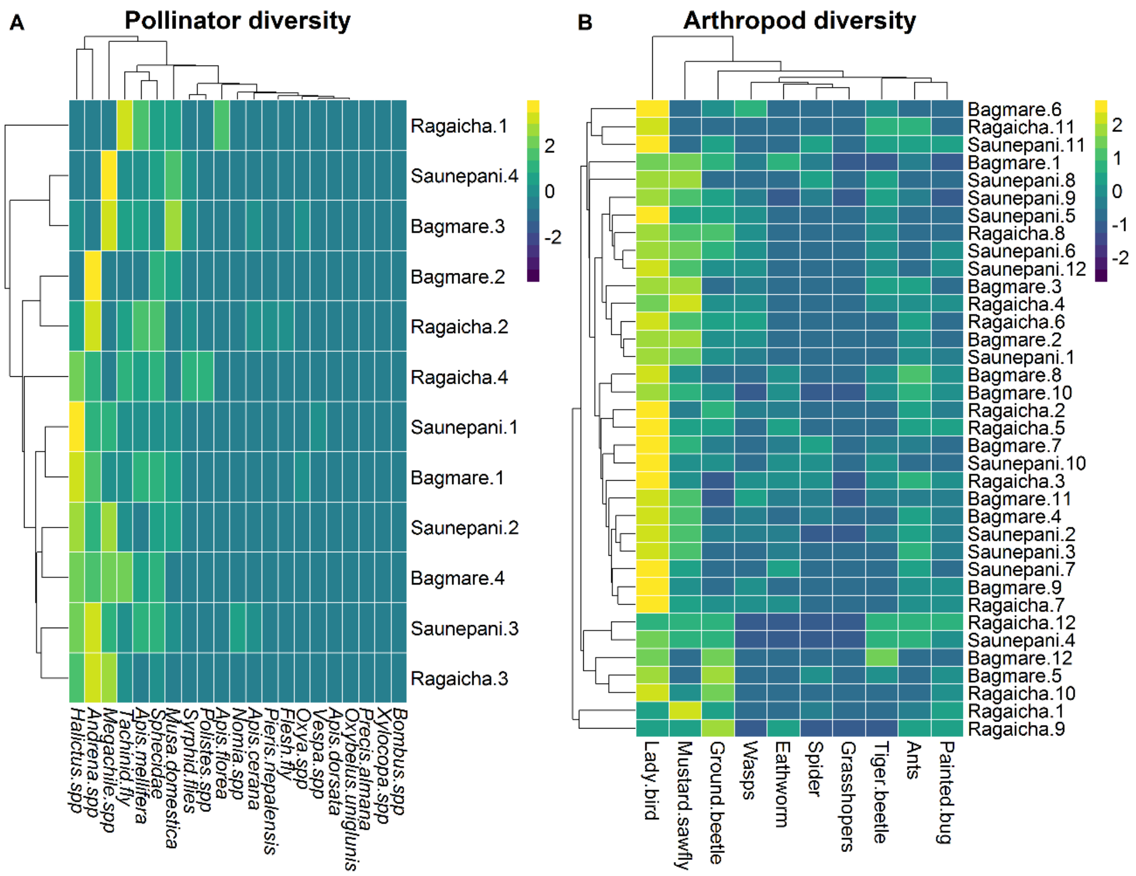


Figure 9. Clustered heatmaps based on fauna of pollinator and arthropod communities

Clustered heatmaps based on fauna of pollinator and arthropod communities along sampling units from three research sites (Bagmare, Ragaicha, Saunepani). Such a hierarchical cluster analysis was carried out after the UPGMA method and Euclidean as a distance measure. The coefficients of cophenetic correlation were 0.98 (pollinator) and 0.70 (arthropod), respectively. Scale color indicates the lower (purple), medium (blue) and higher (yellow) values of sampled specimens.

Citrus crops

Pollinator's diversity

Overall, we collected 616 specimens of pollinators being identified 15 pollinator taxa in our work. We collected higher abundance and richness of the pollinator's taxa in the agroecsoytem practices than in farmer's practices as shown in the table 21 and Figure 10.

Table 211. PERMANOVA parameters and subsequent paired comparison of the composition of the arthropod community associated with research sites, Nepal.

Pratices	Locations	Lattitude	Longitude	Abundance	Richness	Shannon	Simpson
Overall	Balkate	28.068056	83.206667	222	14	2.21	0.85
Overall	Lumcha	28.008889	83.358889	220	15	2.36	0.88
Overall	Pipaldhara	28.0925	83.127222	174	15	2.37	0.88
Agroecosystem practices	Balkate	28.068056	83.206667	126	14	2.2	0.84
Agroecosystem practices	Lumcha	28.008889	83.358889	121	15	2.4	0.89
Agroecosystem practices	Pipaldhara	28.0925	83.127222	101	14	2.34	0.88
Farmers practices	Balkate	28.068056	83.206667	96	13	2.14	0.85
Farmers practices	Lumcha	28.008889	83.358889	79	13	2.21	0.86
Farmers practices	Pipaldhara	28.0925	83.127222	73	15	2.34	0.87

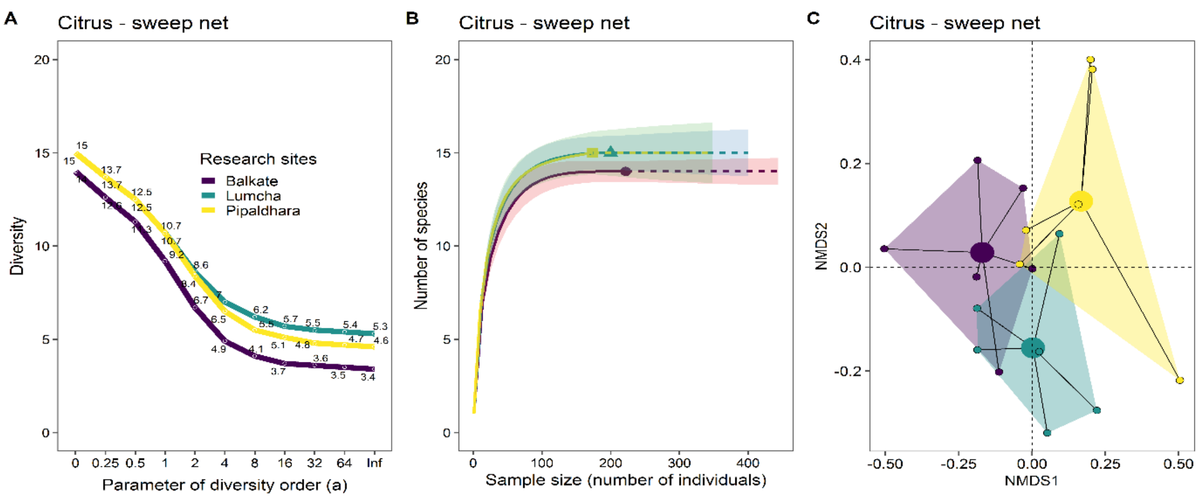


Figure 10. Comparison of practices width (Shannon-Wiener index, H')

Soil Arthropods diversity

Overall, we collected 417 specimens of pollinators being identified 12 in soil arthropdos taxa in our work. We collected higher abundance and richness of the soil arthropods taxa in the agroecsoytem practices than in farmer's practices as shown in the table 22 and Figure 11.

Table 222. PERMANOVA parameters and subsequent paired comparison of the composition of the arthropod community associated with research sites, Nepal.

Practices	Locations	Lattitude	Longitude	Abundance	Richness	Shannon	Simpson
Overall	Balkate	28.068056	83.206667	157	12	2.09	0.84
Overall	Lumcha	28.008889	83.358889	160	12	2.11	0.85
Overall	Pipaldhara	28.0925	83.127222	160	12	1.99	0.82
Agroecosystem practices	Balkate	28.068056	83.206667	106	12	2.17	0.86
Agroecosystem practices	Lumcha	28.008889	83.358889	99	12	2.13	0.86
Agroecosystem practices	Pipaldhara	28.0925	83.127222	98	12	2.08	0.84
Farmers practices	Balkate	28.068056	83.206667	51	8	1.79	0.79
Farmers practices	Lumcha	28.008889	83.358889	62	9	1.91	0.83
Farmers practices	Pipaldhara	28.0925	83.127222	62	10	1.78	0.79

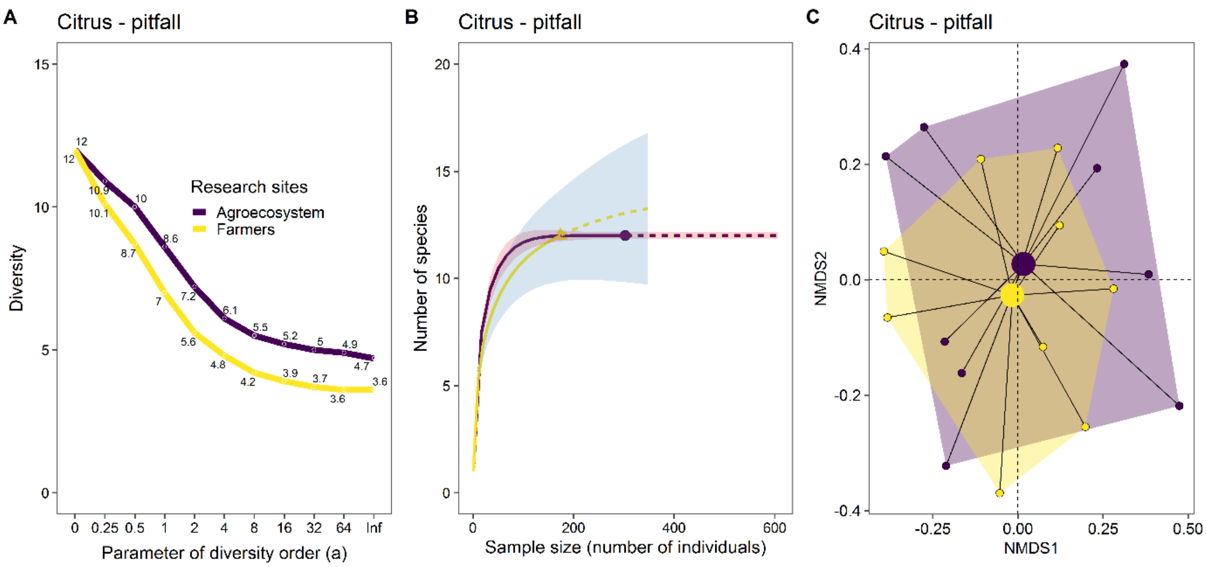


Figure 11. Comparison of practices width (Shannon-Wiener index, H')

Apple crops

Pollinator's diversity

Overall, we collected 563specimens of pollinators being identified 14 pollinator taxa in our work. We collected higher abundance and richness of the pollinator's taxa in the agroecsoytem practices than in farmer's practices as shown in the table 22 and Figure 12.

Table 233. PERMANOVA parameters and subsequent paired comparison of the composition of the arthropod community associated with research sites, Nepal.

Practices	Locations	Lattitude	Longitude	Abundance	Richness	Shannon	Simpson
Overall	Chimang	28.737778	83.706389	173	13	2.26	0.87
Overall	Marpha	28.813056	83.644444	184	13	2.37	0.89
Overall	Pangling	28.819444	83.763333	206	14	2.25	0.86
				563			
Agroecosystem practices	Chimang	28.737778	83.706389	104	13	2.29	0.88
Agroecosystem practices	Marpha	28.813056	83.644444	111	13	2.41	0.89
Agroecosystem practices	Pangling	28.819444	83.763333	128	14	2.29	0.87
Farmers practices	Chimang	28.737778	83.706389	69	12	2.14	0.85
Farmers practices	Marpha	28.813056	83.644444	73	12	2.24	0.87
Farmers practices	Pangling	28.819444	83.763333	78	14	2.16	0.85

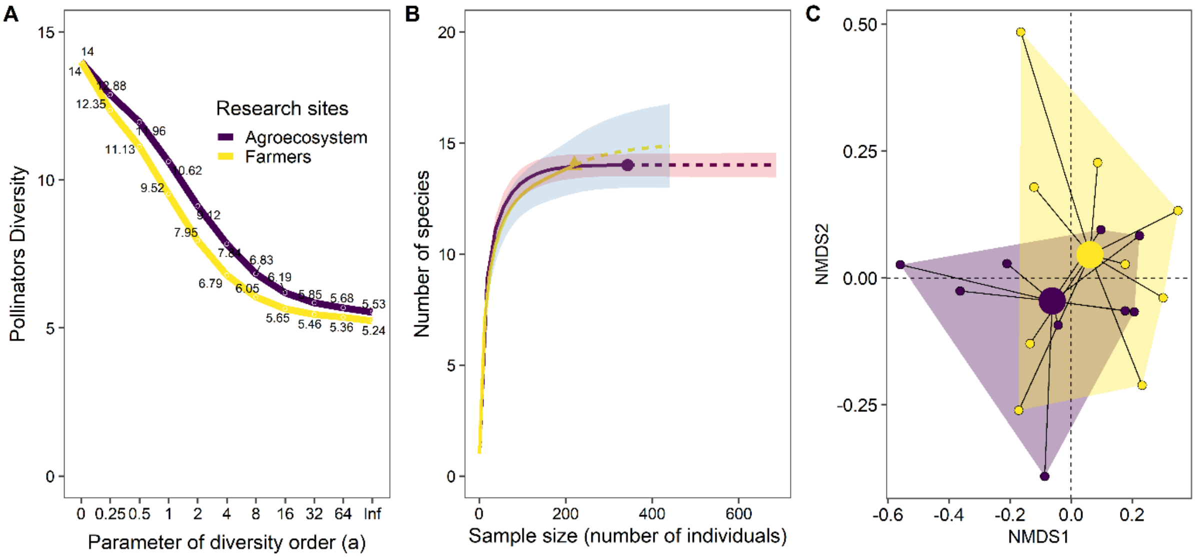


Figure 12. Comparison of practices width (Shannon-Wiener index, H')

Soil Arthropods diversity

Overall, we collected 449 specimens of pollinators being identified 11 in soil arthropdos taxa in our work. We collected higher abundance and richness of the soil arthropods taxa in the agroecsoytem practices than in farmer's practices as shown in the table 24 and Figure 13.

Table 244. PERMANOVA parameters and subsequent paired comparison of the composition of the arthropod community associated with research sites, Nepal.

Practices	Locations	Lattitude	Longitude	Abundance	Richness	Shannon	Simpson
Overall	Chimang	28.737778	83.706389	158	11	2.07	0.85
Overall	Marpha	28.813056	83.644444	133	11	2.02	0.84
Overall	Pangling	28.819444	83.763333	158	11	1.94	0.82
				449			
Agroecosystem practices	Chimang	28.737778	83.706389	104	11	2.17	0.86
Agroecosystem practices	Marpha	28.813056	83.644444	81	11	1.95	0.82
Agroecosystem practices	Pangling	28.819444	83.763333	84	10	1.96	0.82
Farmers practices	Chimang	28.737778	83.706389	54	7	1.71	0.79
Farmers practices	Marpha	28.813056	83.644444	52	8	1.79	0.81
Farmers practices	Pangling	28.819444	83.763333	74	10	1.84	0.8

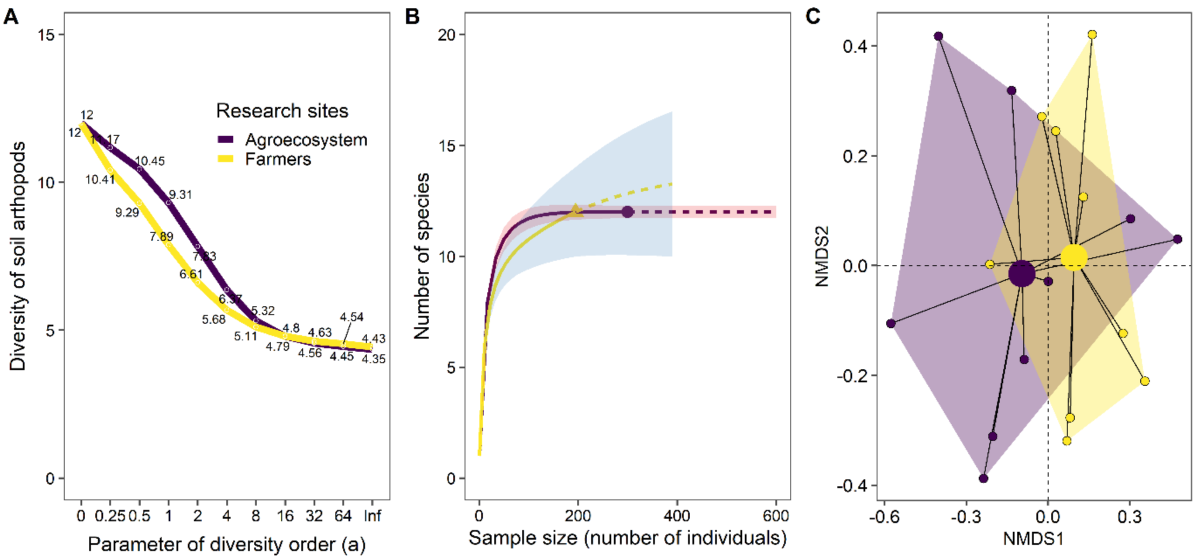


Figure 13. Comparison of practices width (Shannon-Wiener index, H')

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CHAPTER 5

Activity-4: GIS maps and land cover/land escape maps showing the degree of climate change effect on agro-ecosystem services

(Land cover mapping using the GIS of project districts)

5.1 Introduction

Land cover represents the physical and biological cover of the Earth's surface including classes as build-up areas, forests, agricultural areas, wetlands, (semi-) natural areas, and water bodies (Di Gregorio, 2005). On the other hand, the land use represents the present and future planned human activities on a territory (Feranec et al., 2007), characterized as residential, industrial, commercial, agricultural, forestry and leisure. It is the expression of the human activity developed for social, economic, cultural and political purposes. This means that land cover includes the land use features and they should be represented on different maps.

GIS is an integrated system of computer hardware and software capable of capturing, storing, retrieving, manipulating, analyzing, and displaying geographically referenced (spatial) information for the purpose of aiding development-oriented management and decision-making processes (Tziztiki et al., 2012). Remote sensing and GIS have covered wide range of applications in the fields of agriculture, environments, and integrated eco-environment assessment (Yeh and Lei 1998; Long et al., 2008).

5.2 Results

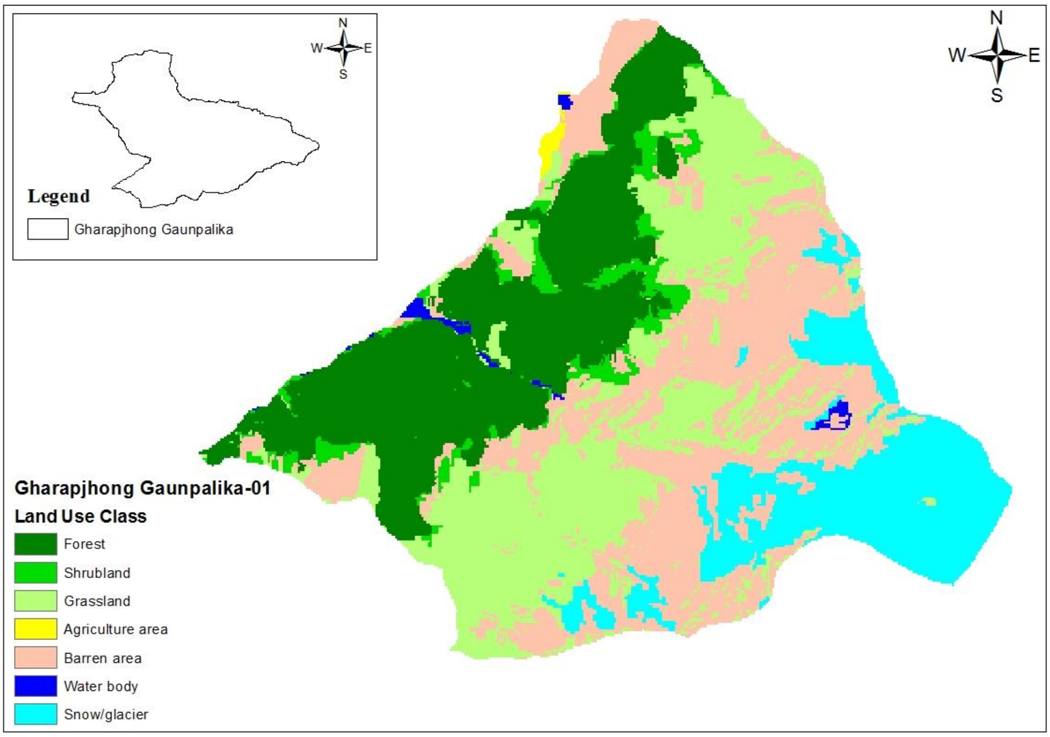

Figure 104.. Land use class of Gharapjhong Gaunpalika Ward # 01, Mustang, Nepal

Table 255. Table showing land use class of Gharapjhong Gaunpalika Ward # 01, Mustang, Nepal

SN	Land Use Class	Area (Hectare)	Area (Sq. km.)
1	Forest	1269.27	12.6927 (25.72)
2	Shrubland	193.41	1.9341 (3.92)
3	Grassland	1281.24	12.8124 (25.96)
4	Agriculture area	14.4	0.144 (0.29)
5	Barren area	1409.85	14.0985 (28.57)
6	Water body	30.51	0.3051 (0.62)
7	Snow/glacier	735.84	7.3584 (14.91)
	Total	4934.52	49.3452 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Gharapjhong Gaunpalika-01 covers 49.35 sq. km of area out of which 28.57% area are barren land followed by grassland (25.96%). About 25.72% area are under forest and 0.29% area are under agriculture.

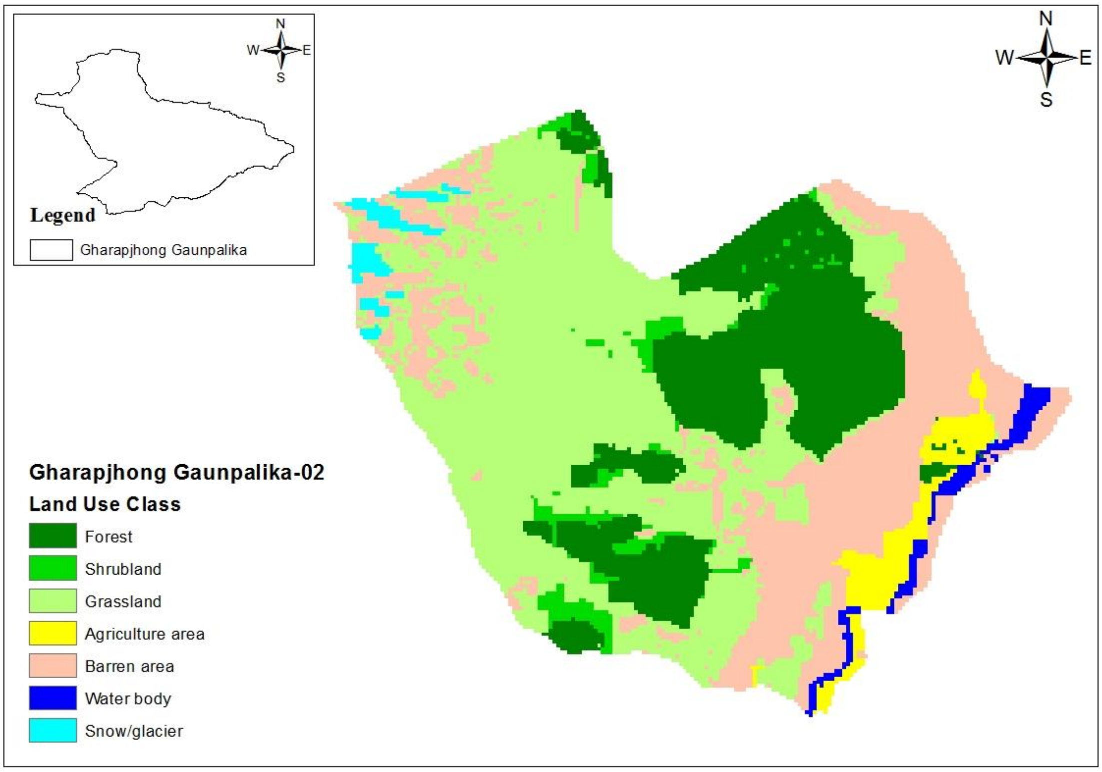

Figure 115. Land Use class of Gharapjhong Gaunpalika -02, Mustang, Nepal

Table 266. Table showing land use class of Gharapjhong Gaunpalika -02, Mustang, Nepal

SN	Land Use Class	Area(Hectare)	Area (Sq. Km.)
1	Forest	362.79	3.6279 (21.73)
2	Shrub land	50.04	0.5004 (3.00)
3	Grassland	709.65	7.0965 (42.51)
4	Agriculture area	62.46	0.6246 (3.74)
5	Barren area	432.18	4.3218 (25.89)

6	Water body	28.17	0.2817 (1.69)
7	Snow/glacier	24.12	0.2412 (1.44)
	Total	1669.41	16.6941 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Gharapjhong Gaunpalika-02 occupies 16.69 sq.km. of area out of which 42.51% area is grassland followed by barren land (25.89)

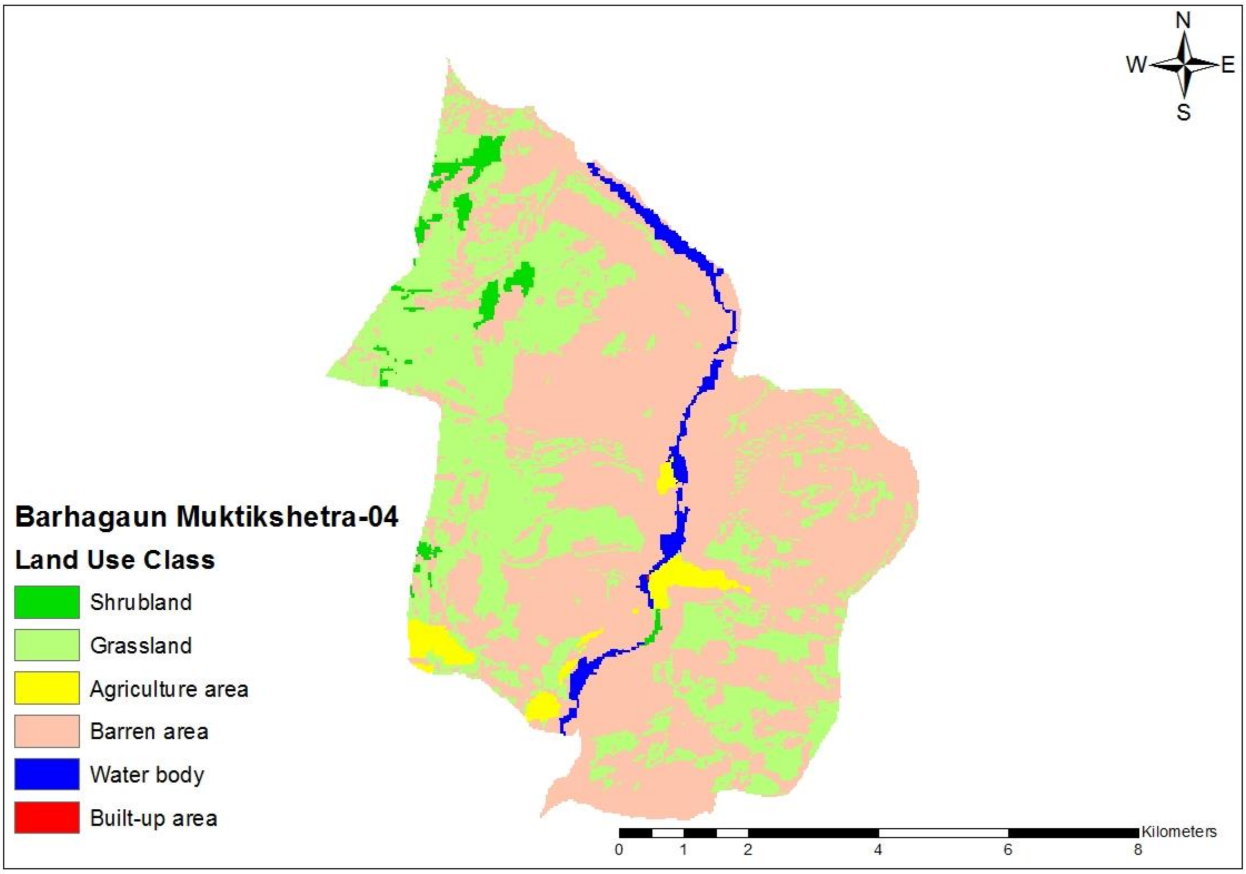

Figure 127. Land use class of Barhagaun Muktikshetra-04, Mustang, Nepal

Table 277. Table showing Land use class of Barhagaun Muktikshetra-04, Mustang, Nepal

SN	Land Use Class	Area (Hectare)	Area (Sq. Km.)
1	Shrub land	103.86	1.0386 (1.78)
2	Grassland	1898.19	18.9819 (32.50)
3	Agriculture area	134.46	1.3446 (2.30)
4	Barren area	3574.8	35.748 (61.21)
5	Water body	128.79	1.2879 (2.21)
6	Built-up area	0.18	0.0018 (0.003)
	Total		58.4028 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Barhagaun Muktikshetra-04 occupies 58.40 sq.km of area of which about 61.21% area is barren land followed by barren land (32.50). About 2.30% area are under agriculture.

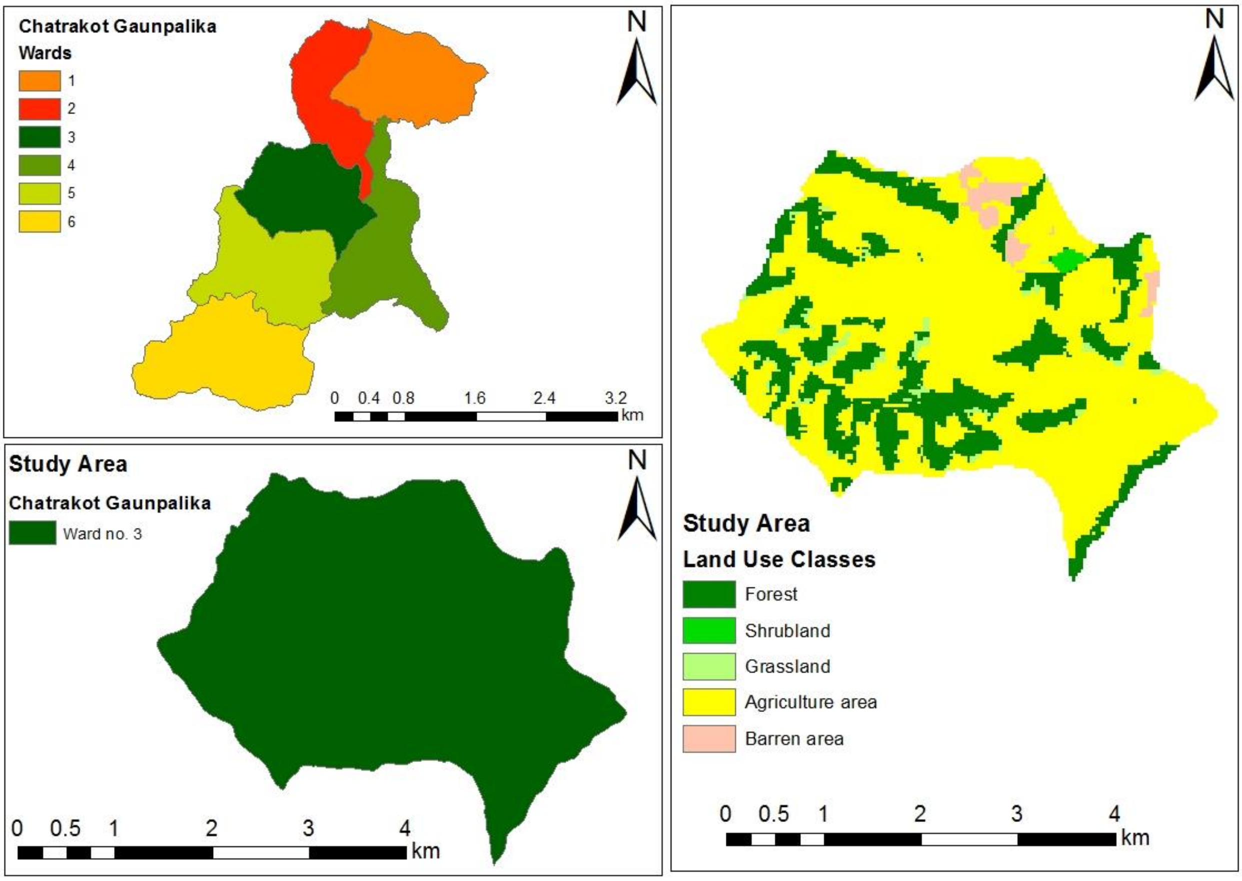

Figure 18. Land Use class of Chatrakot Gaunpalika-03, Gulmi, Nepal

Table 2828. Table showing Land Use class of Chatrakot Gaunpalika-03, Gulmi, Nepal

SN	Land Use Class	Area (Hectare)	Area(Sq.Km.)
1	Forest	318.87	3.1887 (24.49)
2	Shrubland	5.85	0.0585 (0.45)
3	Grassland	32.67	0.3267 (2.51)
4	Agriculture area	913.95	9.1395 (70.19)
5	Barren area	30.78	0.3078 (2.36)
	Total	1302.12	13.0212 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Chatrakot Gaunpalika-03 occupies 13.02 sq.km area out of which about 70% area are under agriculture followed by forest (24.49%).

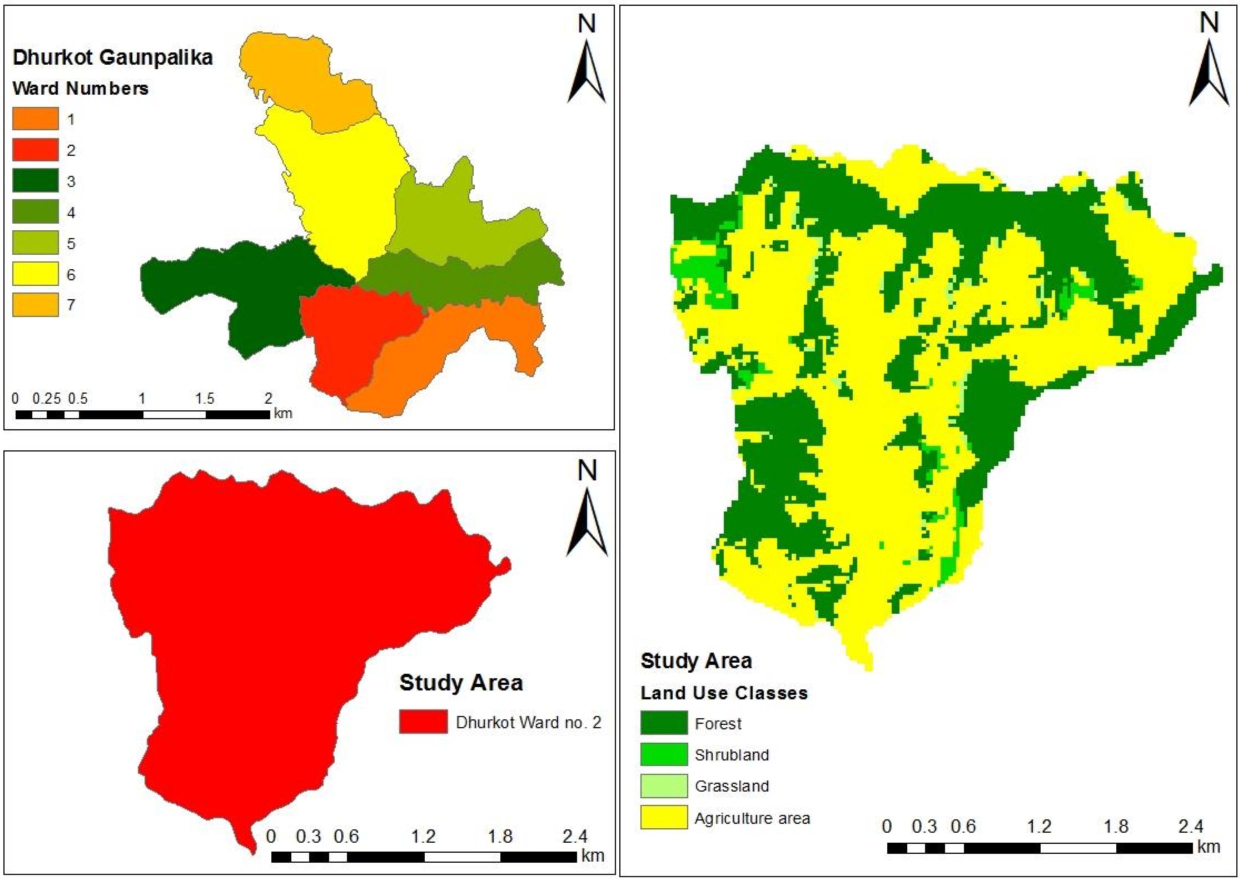

Figure 139. Land Use class of Dhurkot Gaunpalika-02, Gulmi, Nepal

Table 29. Table showing land use class of Dhurkot Gaunpalika-02, Gulmi, Nepal

SN	Land Use Class	Area (Hectare)	Area(Sq. Km.)
1	Forest	394.74	3.9474 (38.86)
2	Shrub land	30.15	0.3015 (2.97)
3	Grassland	14.85	0.1485 (1.46)
4	Agriculture area	576.09	5.7609 (56.71)
	Total	1015.83	10.1583 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Dhurkot Gaunpalika -02 occupies 10.16 sq.km of area out of which 56.71% area are under agriculture followed by forest (38.86%).

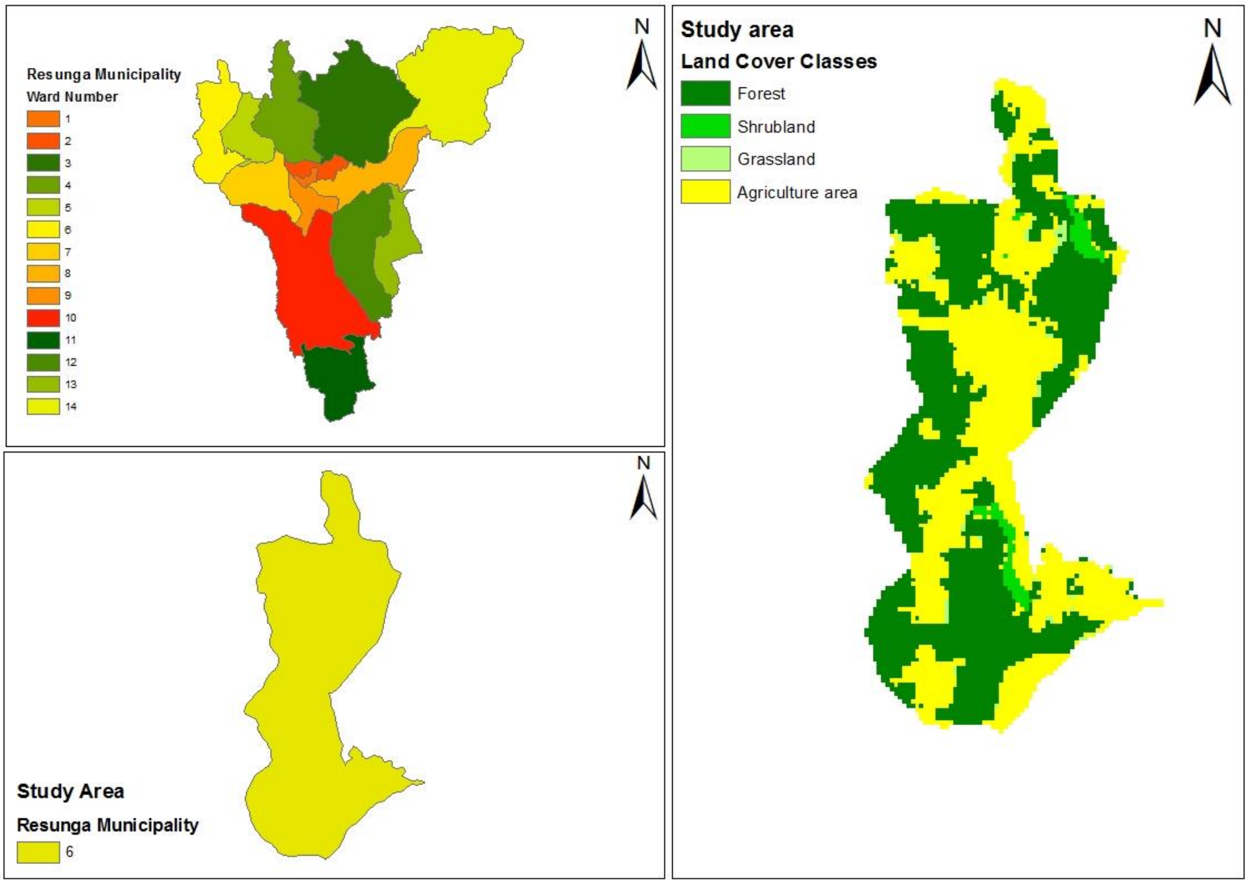

Figure 20. Land Use class of Resunga Municipality-06, Gulmi, Nepal

Table 30.29 Table showing land use class of Resunga Municipality-06, Gulmi, Nepal

SN	Land Use Class	Area (Hectare)	Area (Sq.Km.)
1	Forest	270.72	2.7072 (52.69)
2	Shrub land	12.24	0.1224 (2.38)
3	Grassland	6.12	0.0612 (1.19)
4	Agriculture area	224.73	2.2473 (43.74)
	Total	513.81	5.1381 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Resunga Municipality -06 occupies about 5.13 Sq. Km. of area out of which 52.69 % area is under forest land followed by 43.74 % under agriculture.

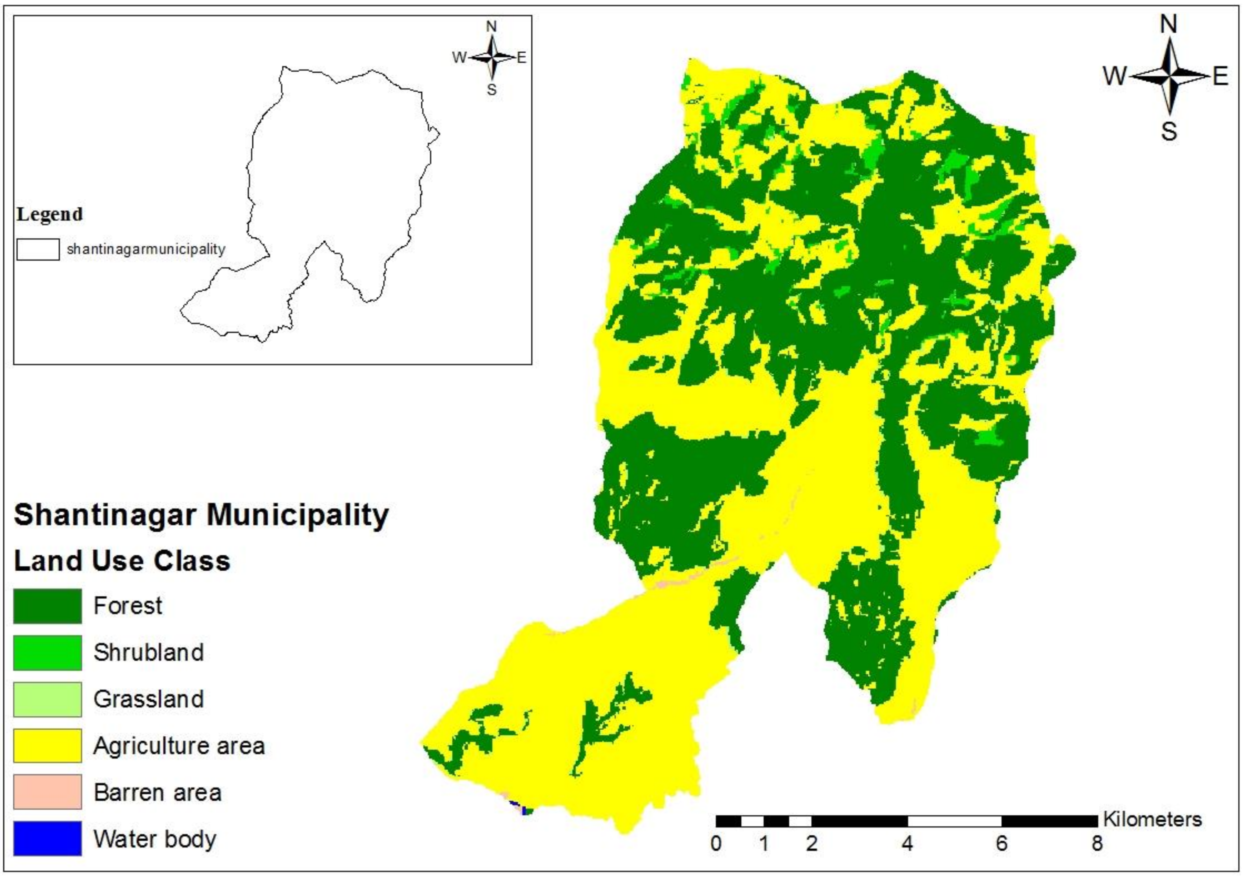

Figure 21. Land Use class of Shantinagar Municipality, Dang, Nepal

Table 31. Table showing land use class of Shantinagar Municipality, Dang, Nepal

SN	Land Use Class	Area (Hectare)	Area (Sq.Km)
1	Forest	5112.45	51.1245 (44.09)
2	Shrub land	278.55	2.7855 (2.40)
3	Grassland	115.65	1.1565 (1.00)
4	Agriculture area	6062.67	60.6267 (52.28)
5	Barren area	24.12	0.2412 (0.21)
6	Water body	3.06	0.0306 (0.03)
	Total	11596.5	115.965 (100)

(Note: Number is parenthesis denotes percentage area occupied)

Shantinagar municipality occupies 115.97 sq. km. of area. Out of total area about 52% area are under agriculture followed by forest (44.09%).

5.3 References

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CHAPTER 6

Activity-5: Soil health improvement

6.1 Introduction

Intensification of agriculture has resulted overall deterioration in soil-based ecosystem making soil poor reserve of micro-organisms, nutrients and organic matter leading to loss of biodiversity, thereby damaging sustainability of agricultural production, soil resilience capacity, and environmental quality. The capacity of the soil system to supply nutrients and retain applied nutrients is undermined by practices that diminish the role of soil organisms and lead to depletion in soil organic matter. In general, plants serve as carbon source for the microbial community and in turn microbes provide nutrients for growth through mineralization of plant and animal residues, and organic matter, thus soil microbial biomass is a significant parameter to draw an inference about the soil health (Dwivedi and Soni, 2011). Therefore, appropriate application of targeted, sufficient, and balanced quantities of soil nutrients and soil management is necessary to make nutrients available for high yields of crops without polluting the environment.

Soil being reservoir of life is a rich source of microorganisms responsible for its most important functions in terrestrial ecosystems. Interaction between edaphic microorganisms and plants usually determines the biodiversity of vegetation. The level of soil microbial biomass and the activity of top soil organisms are important factor in determining soil health, and soil microbial biomass has been used as an index of soil fertility. Microbial communities may also be used as parameters of soil health because the ecological equilibrium between pathogens and biocontrol agents naturally suppresses the incidence of diseases. Some of the microorganisms available in the soil are very beneficial for the agriculture which are discussed below.

Trichoderma

Trichoderma refers to the genus of fungi, which mostly have a mutualistic relationship with plants, which typically grow fast at 25°-30°C but can grow well up to 45°C. *Trichoderma* spp. has been used as biocontrol agents due to their specific mechanisms, like antibiosis, parasitism, host-plant resistance and competition, and they have now been popular both as biofertilizer and biopesticide. *Trichoderma* spp. play importance roles in growth, yield and nutritional quality of various crops (Molla et al., 2012; Saravanakumar et al., 2017). *Trichoderma*, being a fungus, affects positively or negatively to higher plants. It is highly interactive in root, soil and foliar environments. It reduces growth, survival or infections caused by pathogens by its different mechanisms, like competition, antibiosis, mycoparasitism, hyphal interactions and enzyme secretion.

Azotobacter

Azotobacter spp. are the free-living bacteria, which grow well on a nitrogen free medium. These bacteria utilize atmospheric nitrogen gas for their cell protein synthesis. They are ubiquitous and abundantly found in neutral to weakly acidic soils. In dry soils, *Azotobacter* can survive in the form of cysts for up to 24 years. *Azotobacter* enhanced biofertilizer plays significant role in plant growth (Wani et al., 2016).

Actinomycetes

Actinomycetes are aerobic spore forming gram-positive bacteria. They are the most abundant organisms that form thread-like filaments in the soil and are responsible for characteristically "earthy" smell of freshly turned healthy soil. They play major roles in the cycling of organic matter; inhibit the growth of several plant pathogens in the rhizosphere and decompose complex mixtures of polymer in dead plant, animal and fungal material results in production of many extracellular enzymes which are conductive to crop production. The major contribution in biological buffering of soils, biological control of soil environments by nitrogen fixation and degradation of high molecular weight compounds like hydrocarbons in the polluted soils are remarkable characteristics of *Actinomycetes*. Besides this, they are known to improve the availability of nutrients, minerals, enhance the production of metabolites and promote plant growth regulators. They decompose the more resistant and un-decomposable organic substance/matter and produce a number of dark black to brown pigments, which contribute to the dark color of soil humus. They are also responsible for subsequent further decomposition of humus (resistant material) in soil. Therefore, first and foremost step is the soil analysis to determine their present status and initiate necessary actions for healthy soil formation and beneficial micro-organism conservation.

Table 32. Microorganisms supporting in ecosystem services

Ecosystem services	Microorganisms providing the services
Organic matter decomposition and cycling	Bacteria, actinomycetes, fungi, especially belonging to cellulolytic group (e.g. species from genera *Cytophaga*, *Chaetomium*, *Mortierella*, *Epicoccum*).
Improving nutrients availability and uptake	Majority of bacteria, actinomycetes (nitrogen mineralizing species of Streptomyces from Series Griseus), microfungi, ecto or endo-mycorrhizal fungi forming symbioses with trees (e.g. basidiomycetes).
Suppression (inhibition) of plant pathogens	Antagonistic species of bacteria (e.g. *Pseudomonas fluorescens),* actinomycetes, fungi (e.g. *Trichoderma viride, Paecilomyces* sp.)
Plant growth control	Plant growth promoting microorganisms, mycorrhizal fungi, biocontrol agents (antagonists for pathogens).
Improving soil structure and hydrological processes	Bacteria producing exopolysaccharides (pseudomonads), actinomycetes, fungi, (e.g. species from genera *Humicola*, *Trichoderma*, *Myrothecium*, *Cladosporium*), mycorrhizal fungi, all contributing to formation of soil aggregates.
Regulation sequestration of gas exchange and carbon	Microorganisms from all groups, mostly from cellulolytic group

Source: Matei et al., 2020.

6.2 Objectives

- To determine the status of micro-organisms on soil samples in the project sites in Dang, Gulmi & Mustang.
- To make aware the farmers on the importance of soil micro-organisms for crop production.

- To recommend suitable management measures to maintain micro-organisms and soil fertility and sustaining crop productivity.

6.3 Methodology

Sampling is the vital step for soil micro-organism analysis, which were collected following soil testing standards from farmers' fields as representatives of the selected areas. Altogether 30 soil samples were collected from the project districts Dang, Gulmi and Mustang. Ten fields were selected from each districts representing all the project sites randomly. In the Dang district, the soil sampling was carried out before the cultivation of the Maize and before the manuring on the Citrus in Gulmi and Apple fields, Mustang in the month of January-February 2020. For this, surface litter was scraped away without disturbing soil, V-shaped cut up to 15 cm depth, and soil slices collected in plastic bucket moving in a zig-zag manner from each sampling unit in the case of the Maize whereas in Citrus and Apple soil sample were taken from the three layers i.e 0-15 cm, 15-30 and 30-60 cm. Five soil samples were collected from homogenous sampling units, mixed them thoroughly, which were divided into four units and two opposite units were selected each time so that the final composite sample of 400 gm (one sampling unit) was selected. Thus, collected samples kept in plastic bags, well labeled, brought in Laboratory for analysis.

The plate-count technique (modified dilution-plate method as described by Johnson and Curl (1972) was used for determining numbers of *Trichoderma*, *Azotobacter* and *Actinomycetes*. Briefly, the soil was shaken in a sterile flask and suspensions prepared. Plate of a specific medium for each microorganism was prepared. To study the microorganism present in the soil, the suspension was diluted to 10^{-4}. These petri plates were incubated in an inverted condition for three to five days at 30◦C for fungi and 37◦C for bacteria, *Azotobacter* and *Actinomycetes* colony formation. After incubation, colonies were counted.

6.4 Results

Farmers' knowledge on the microorganism

The farmers' survey revealed that overall, more than 80% of the farmers are unknown about the soil beneficial microorganism. The farmers from the Gulmi and Mustang didn't have any knowledge on the soil microorganism as shown in Table 29.

Table 30 Farmer's knowledge on the soil microorganism in the project districts.

SN	Knowledge on soil microorganism	Dang	Gulmi	Mustang	Total	P value
1.	Yes	55 (46.2%)	0 (0.0%)	0 (0.0%)	55 (18.8%)	< 0.001
2.	No	64 (53.8%)	114 (100.0%)	60 (100.0%)	238 (81.2%)	

Status of soil microorganisms in the project sites

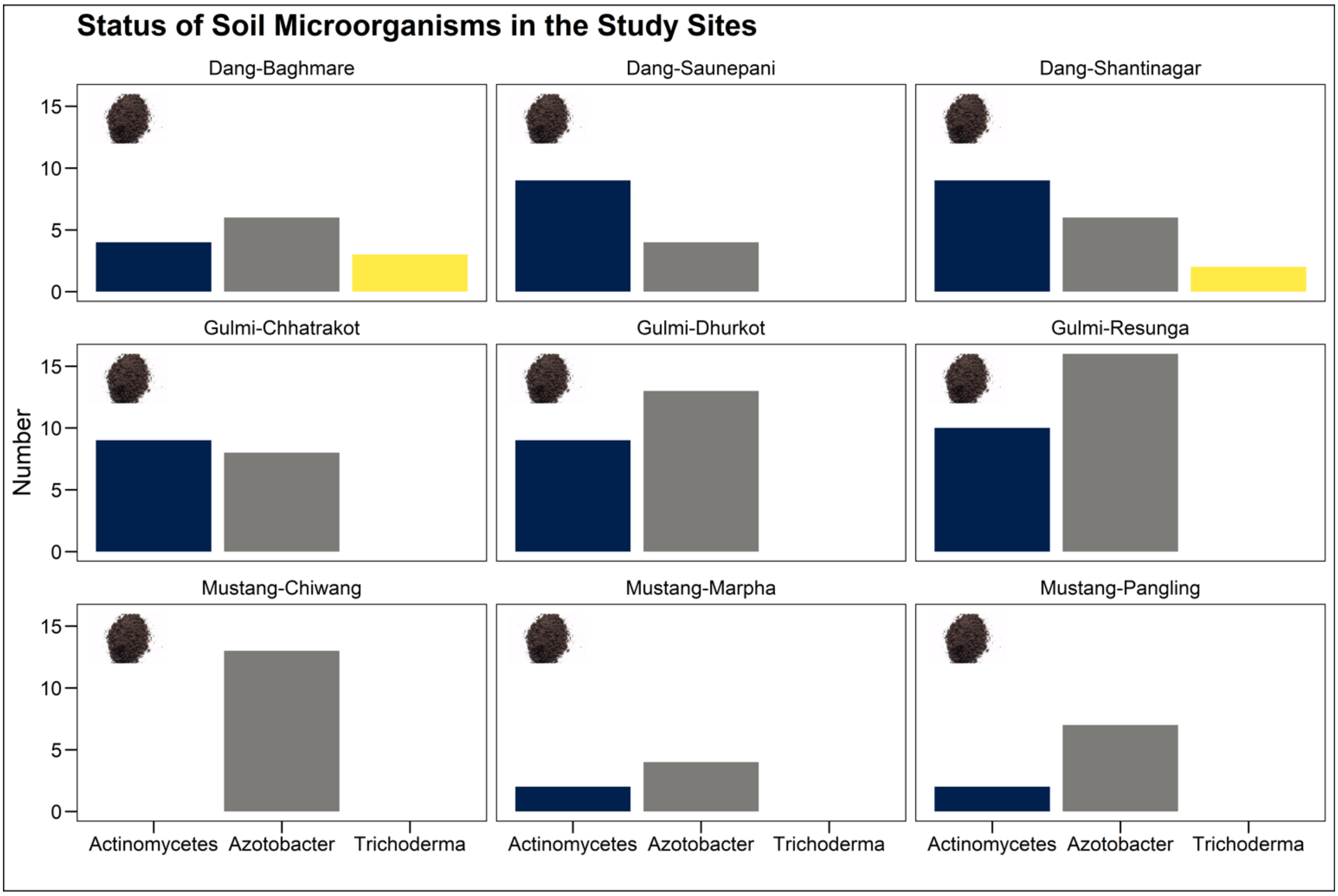

Figure 2214. Status of the soil micro-organism in the project sites

The figures show, three microorganisms *Actionomycetes, Azotobacter* and *Trichoderma* were presented in the soil sample taken from the two project sites Baghmare and Shantinagar whereas *Trichoderma* population was nill in Saunpani sites of the Dang districts. Similarly, *Actinomycetes* and *Azotobacter* were found in three sites Chatrakot, Dhurkot and Resunga of Gulmi whereas there was no population of the *Trichoderma* found. In case of Mustang, *Azotobacter* was found in the three sites whereas *Actinomycetes* was found in Marpha and Pangling. The *Trichoderma* population was also found Nil in all the project sites of Mustang.

Status of soil microorganisms in the project districts

The status of the soil microorganisms were shown in table 30. We found that the *Trichoderma* microorganism population was not traced in the 10^{-4} diluted solution in the two districts as shown in table 2. In Dang, out of 10 samples analyzed it occurred only in 4 samples in the 10^{-4} diluted solution (refer appendix). It ranged from 0 to 3 with an average of 0.80 cfu/g of soil.

Table 31. Soil microorganisms Trichoderma, Azotobacter and Actinomycetes (cfu/g) of soil in sample analysis of from Dang, Gulmi and Mustang districts

SN	Statistical value	Trichoderma	Azotobacter	Actinomycetes
1	Dang	0.8 (1.14)	3.7 (2.16)	3.8 (3.12)
2	Gulmi	-	8 (4.50)	5.6 (2.67)
3	Mustang	-	5.5 (4.22)	0.4 (0.84)

*Figures in the parentheses indicated the standard deviation.

The soil microorganism, *Azotobacter* occurred in 90% of the samples in all selected districts (refer appendix) - Dang, Gulmi and Mustang (Table 30). The count was the highest in soil samples from Gulmi with mean of 8.0 (range 0-16) followed by Mustang with mean of 5.5 (range 0-13) and Dang with mean of 3.7 (range 0-6) cfu/g of soil, respectively. The soil micro-organism *Actinomycetes* also occurred in all 10 samples in Gulmi, 8 samples in Dang and only in 2 out of 10 samples in Mustang district (refer appendix). Mid hill (Gulmi) soil represented high count (mean 5.6 and range 3-10), followed by Dang (mean 3.8 and range 0-9) and Mustang (mean 0.4 and range 0-2) *Actinomycetes* cfu/g of soil, respectively.

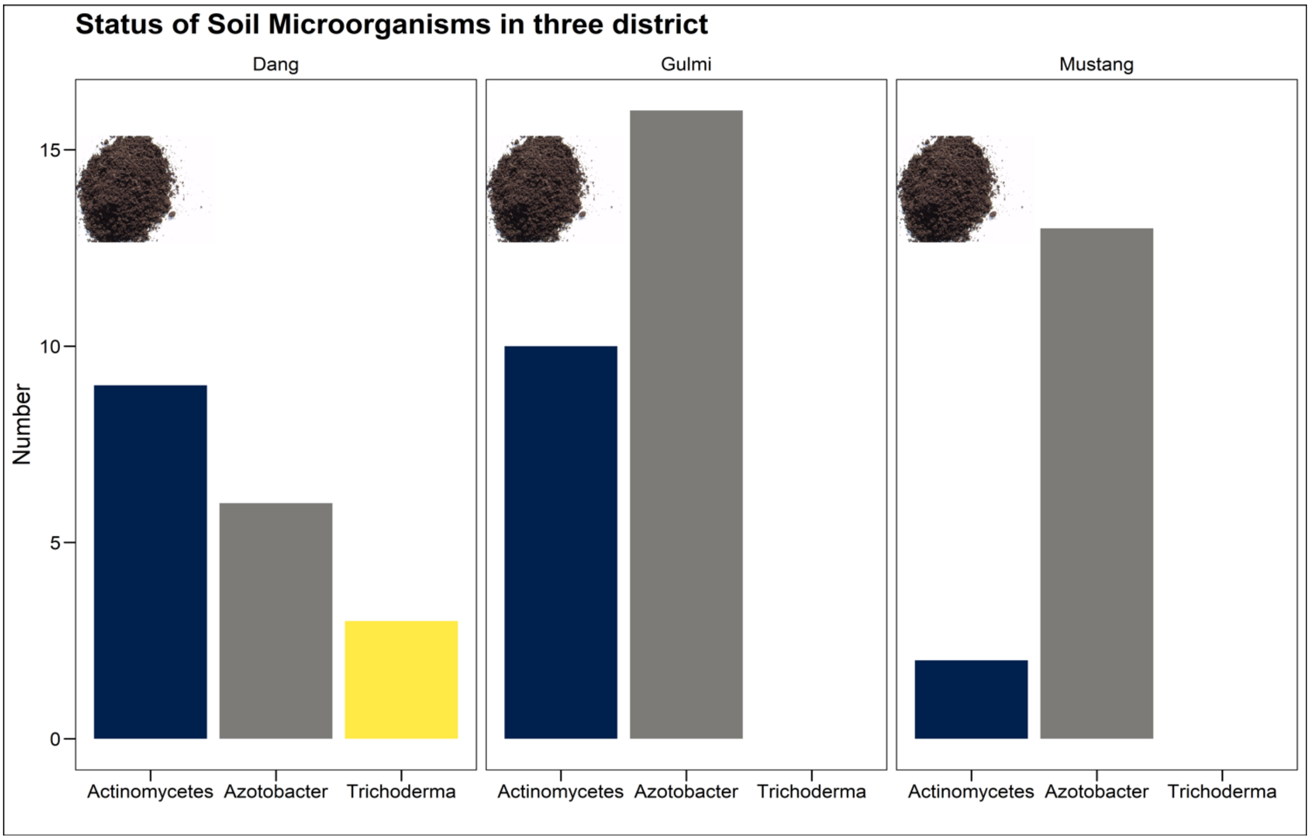

Figure 23. Shows the status of the soil microorganisms in the project districts

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Baseline and endline report

We conducted the both baseline soil survey and endline survey in the farmer's field scholl (FFS) agroecosystem plots. The basi soil nutrients like Oganic matter, Nitrogen, Phosphorous and Potassium were analysed. The remarkeable change was found during the two years periods in soil nutrients status as shown in figure 24. Along this we also conducted the soil microorganism study in the FFS fields in the baseline and endline. We found remarkable improvement in the soil microorganism status in the Dang and Gulmi district but no changes was observed in the Mustang district as shown in figure 25.

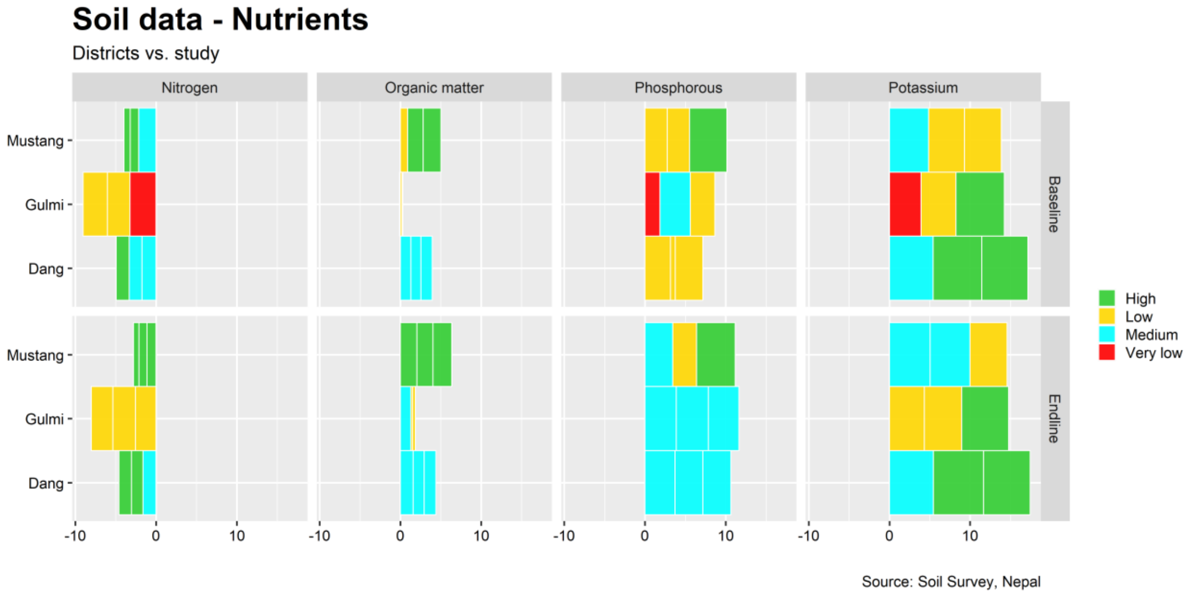


Figure 24. Shows the status of the soil microorganisms in the project districts

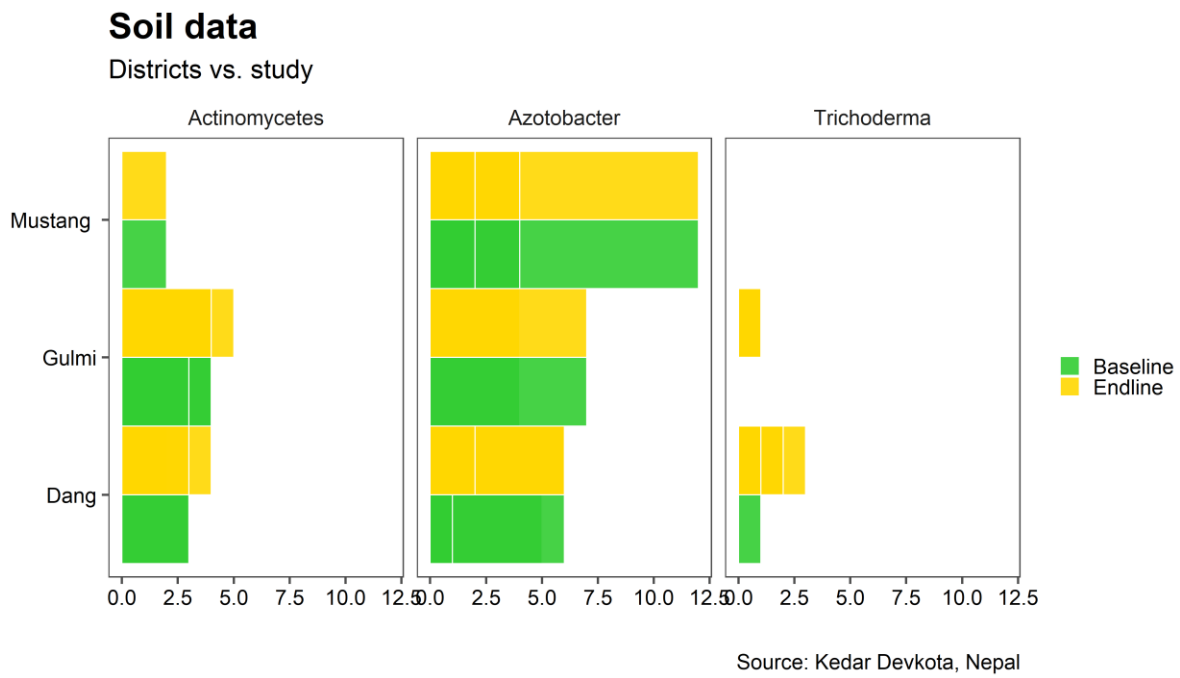


Figure 25. Shows the status of the soil microorganisms in the project districts

6.5 Management strategy

Soil is considered as a complex and dynamic biological system that provides diverse habitats for the microbial community and is a hotspot for belowground microbial interactions. Table 31 shows the presence of number and biomass of microbial species at upper depth of soil. The soil microbial community acts as a central factor in mediating the key ecosystem services and functions. Only a small fraction of soil microorganisms have been cultured and studied because only about 1% of microbes are culturable, the uncultured microbiota is considered as a treasure trove of the microbial world. Therefore, exploring this hidden resource is important, especially for agriculture.

Table 32. Relative numbers and biomass of microbial species at 0–15-cm depth of soil

SN	Microorganisms	Number per gm of soil	Biomass (g/m^2)
1	Bacteria	10^8–10^9	40–500
2	Actinomycetes	10^7–10^8	40–500
3	Fungi	10^5–10^6	100–1500
4	Algae	10^4–10^5	1–50

Source: Adu and Oades, 1978.

The soil microbial population consisting of bacteria, fungi and micro-fauna (microscopic) are termed as soil microbial biomass (SMB). The soil biota includes vast numbers of microorganisms that naturally reside in soil and perform a wide range of functions which are essential for a normal and healthy soil. Total carbon and soil microbial biomass present in different land use system are shown in table 32. Data presented reveals the relationship between the SOC with SMB, which shows that the conversion of forests and pasture lands into other land uses has resulted in remarkable decline in the amounts of soil nutrients and soil microbial biomass. While, global averages for SMB-C are 700, 1090, 850 for cultivated, grassland and forest soils, respectively, which range from 110 kg- C/ ha in a cultivated field with total C of 0.7% to 2240 kg- C/ha in a grassland soil with total C 7.0% (Smith and Paul, 1990). For SMB-N the values are 195, 225 and 170 for cultivated, grassland and forest soils, respectively.

Table 33. Soil microbial biomass in different land uses and plantations

SN	Land use/plantation	Total C (%)	Microbial biomass (μg g^{-1} of soil)
1	Crop field	1.06	250.00
2	Pasture	2.53	659.00
3	Mixed grass	0.37	49.95
4	Savanna	1.20	397.00
5	Forest	2.18	609.00
6	Mine spoil	NA*	332.00
7	*Acasia*	0.51	104.64
8	*Vetiveria*	0.58	135.14
9	*Desmostachya*	0.71	195.25
10	Pine forest	0.53	121.00

Source: Dwivedi, and Soni, 2011

The soil microbial biomass influences the availability of amount of the carbon and other nutrients importantly N and P for plants. Data presented in Table 33 shows that importantly play role in N fixation, Phosphorous and Potash solubilization, Iron reduction and their availability to different crop species through their various mechanisms.

Table 34. Microbial traits that enhance nutrient uptake by plants

SN	Microorganism	Crop species	Nutrient	Mechanism
1	*Rhizobium* spp.	*Phaseolus vulgaris*	N	Symbiotic nitrogen fixation
2	*Bradyrhizobium japonicum*	*Glycine max*	N	Symbiotic nitrogen fixation
3	*Frankia* spp.	*Discaria trinervis*	N	Symbiotic nitrogen fixation
4	*Frankia* spp.	*Casuarina* spp	N	Symbiotic nitrogen fixation
5	*Azospirillum brasilense*	*Oryza sativa*	N	Non-symbiotic nitrogen fixation
6	*Azospirillum. brasilense*	*Triticum aestivum*	N	Non-symbiotic nitrogen fixation
7	*Azotobacter* spp.	*Heliantus tuberosus*	N	
8	*Herbaspirillum* spp. and *Burkholderia vietaminensis*	*Oryza sativa*	N & P	Phosphorous solubilization; and promotion of N use efficiency
9	*Bradyrhizobium*	*Ipomoea batatas*	N	Non-symbiotic nitrogen fixation
10	*Pseudomonas putida*	*Hordeum vulgare*	P	Phosphorous solubilization by acidification
11	*Sinorhizobium meliloti*	*Medicago truncatula*	P	Phosphorous solubilization by acidification and phosphatase activity
12	*Piriformospora indica*	*Zea mays*	P	Phosphate transport
13	*Bacillus mucilaginosus*	*Sorgum vulgare*, *T. aestivum* and *Z. mays*	K	Potassium solubilization
14	*Arthrobacter agilis* UMCV2	*Phaseolus vulgaris*	Fe	Iron reduction/ solubilization
15	*Arthrobacter agilis* UMCV2	*Medicago truncatula*	Fe	Plant strategy I induction

Source: Gupta et al. (eds.), 2016.

The soil enzymes are known to function in both nutrient cycling and soil organic matter decomposition (Table 34), which are also equally important in plant nutrient utilization by plants and management in soil fertility. Some of the alkaloids produced by the micro-organisms, such as fungal endophytes also are effective against different crop insect pests- aphids, fall armyworm, flies and weevils (Table 35).

Table 35. Some important soil enzymes and their functions in both nutrient cycling and soil organic matter decomposition

SN	Enzyme	Substrate	Enzyme reaction	Significance of enzyme
	Nutrient cycling			
1	Amidase	Carbon and nitrogen compounds	N-mineralization	Plant available NH4+
2	Phosphatase	Phosphorous	Release of PO43+	Plant available P
3	Sulphatase	Sulphur	Release of SO42-	Plant available S
4	Urease	Nitrogen	Release of NH3 & CO2	Plant available NH4+
	Decomposition of organic matter			
5	β-glucosidase	Carbon compounds	Cellulose hydrolysis	Energy for microorganisms
6	Fluorescein diacetate (FDA) hydrolysis	Organic matter	Carbon and various nutrients	Energy for microorganisms as measure of microbial biomass

Source: Yang et al., 2015.

Table 36. Alkaloids produced by fungal endophytes against insects

SN	Endophytic fungi	Alkaloids	Effective to insect pests
1	Balansiae cyperi	Agroclavine	Spodoptera frugiperda
2	Neotyphodium coenophialium	Pyrrolopyrazine	Argentine stem weevil
3	Acremonium coenophialum, Epichloe typhina	Loline, peramine	Aphids
4	Nodulisporium sp.	Nodulisporic acid A	Aedes mosquito, blowfly

Source: Gupta et al. (eds.). 2016.

Compost manuring, such as use of FYM/Poultry manure Vermi-compost is always beneficial to plants and soils in many aspects. This has been exemplified with the use of Vermi-compost and comparing with chemical fertilizers (Table 36). Vermi-compost application supersedes chemical fertilizer in all aspects, i.e., availability of NPK, carbon biomass and soil micro-organisms.

Table 37. Farm soil properties under vermi-compost and chemical fertilizer

SN	Chemical and biological properties of soil	Vermi-compost	Chemical fertilizers
1.	Availability of nitrogen (kg/ha)	256.0	185.0
2.	Availability of phosphorus (kg/ha)	50.5	28.5
3.	Availability of potash (kg/ha)	489.5	426.5
4.	Azatobacter (1000/gm of soil)	11.7	0.8
5.	Phospho-bacteria (100,000/kg of soil)	8.8	3.2
6.	Carbonic biomass (mg/kg of soil)	273.0	217.0

Source: Suhane, 2007.

Bio-fertilizers, like *Rhizobium*, *Azotobacter* and *Azospirillium* because of their beneficial nature to plants and soils have been produced commercially and used by the farmers in different crops as seed and soil treatments (Table 37).

Table 38. Some beneficial organisms used as bio-fertilizers in vegetables

SN	Organism	Mode of action	Use in crops	Method of treatment	Dose (g/ha)
1.	Rhizobium	Symbiotic N fixation	Leguminous vegetables	Seed treatment	600
2.	Azotobacter	Asymbiotic N fixation	Vegetables	Seed treatment	3,400
3.	Azospirillum	Asymbiotic N fixation	Vegetables	Seed treatment Soil application	1,000 2,000
4.	PSM	Phosphorus solubilization	Vegetables	Seed treatment	600

Source: Chaudhari et al., 2014.

6.2 Introduction

Soils are integrated components of ecosystem (croplands, pasturelands, woodlands etc.) as a precious asset of nature for all life on earth. Soil is a base to prosperous agriculture but deteriorated due to many reasons: land clearing, deforestation, over grazing, surface mining, industrial wastes, and careless management. Further, climate has a significant effect on crop growth, production and productivity, quality and economic returns. Soil is constantly changing and always responding to changes in the environmental factors, along with the influences of man and land use.

The biggest challenge for agriculture over the coming decades will be to meet the world's increasing demand for food in a sustainable manner. Therefore, good land management decision is needed for sustainable and resilient agriculture systems. In fact, agriculture has been considered as the backbone of the national economy, food security of the country and livelihood of farm families. It implies all activities which need to be undertaken for crop production, like land preparation, soil fertility, crop varieties, sowing, inter-culture practices, bio-rational pest management and harvesting of crops with least disruption to the environment. It is necessary to produce crops maintaining soil fertility with balanced fertilization, ensuring healthy agro-ecosystem with biological diversity and conservation of all organisms for getting good ecosystem services from generation to generation. For all these, the basic requirement is soil sampling analysis and application of the results for maintaining sound agro-ecosystem and bio-diversity. In this line, FAO had declared the year 2015 as the "International Soil Year" and 5th December as World Soil Day with an aim to raise awareness about the importance of healthy soil and their sustainable management for protection for this precious natural resource.

6.2.1 Objectives

- To study the farmers knowledge on the importance of balanced use of nutrients for crop production.
- To determine the status of soil and calculate index of nutrient availability of farmers' fields.
- To predict the probability of profitable response to fertilizer.
- To recommend fertilizer needs of crops to maintain soil fertility and sustain food productivity.
- To maintain judicious use of input, i.e., reducing unnecessary costs and help in soil fertility management.
- To share technology generated for nutrient use efficiency and promote environment quality.

6.2.3 Methodology

Soil fertility is an important ecosystem services for cultivation of any type of crop. Crop yield is largely dependent on the soil in which the crop grows. So, before cultivation, it is very important to check the soil for its nutrients. Therefore, semi-structured questionnaire was prepared, shared with FAO office for suggestion and improvement, and face to face interview was administered among randomly selected farmers in Dang, Gulmi and Marpha including farmers as follows.

Dang	Gulmi	Marpha
1. Ragauja (N=23) 2. Sunepani (N=20) 3. Santinagar (N=25)	1. Balkot (N=21) 2. Lumcha (N=17) 3. Pipaldhara (N=16)	1. Gharapjing (N=6) 2. Marpha (N=6) 3. Pangling (N=10)
Total: 68	Total: 54	Total: 22

Similarly, soil sampling is the vital step for analysis, which were collected following soil testing standards from farmers' fields as representatives of the selected areas. It was done when there was no crop in the field, before growing of the next crop and prior application of manures and fertilizers. For this, surface litter was scraped away without disturbing soil, V-shaped cut up to 15 cm depth, and soil slices collected in plastic bucket moving in a zig-zag manner from each sampling unit in the Dang districts. In Gulmi and Mustang, the soil samples were taken from the Citrus and Apple field before the manuring on the crops. The soil samples were taken from the three depths i.e 0-15 cm, 15-30 cm and 30-60 cm depths. Ten soil samples were collected from homogenous sampling units, mixed them thoroughly, which were divided into four units and two opposite units were selected each time so that the final composite sample of half kg (one sampling unit) was selected. Thus collected samples kept in cloth bags, well labeled, brought in Soil Testing Laboratory in Pokhara, Kaski. Soil analysis was done for major primary nutrients N, P, K, including soil pH and organic matter.

6.2.4 Results

Farmers' survey

Farmer's perception on the soil fertility status of the soil

Farmers were interviewed from the three project districts i.e Dang (120), Gulmi (120) and Mustang (60) to know their perception on the soil fertility status of soil. In total 54.9% of the farmers perceived that the soil in the field was fertile followed by the somewhat fertile (32.8%), highly fertile (9.6%) and least (2.7%) perceived as not fertile. There results from the districts was contrasting showing that the majority of the farmers from the Dang districts perceived the soil are somewhat fertile whereas in the Gulmi and Mustang districts majority of farmers perceived as fertile shown in Table 39.

Table 39. Farmer's perception on the soil fertility status of the soil in the project districts

SN	Soil fertility status	Dang	Gulmi	Mustang	Total	P value
1.	Fertile	38 (31.9%)	77 (67.5%)	46 (76.7%)	161 (54.9%)	< 0.001
2.	Highly fertile	0 (0.0%)	28 (24.6%)	0 (0.0%)	28 (9.6%)	
3.	Not fertile	6 (5.0%)	2 (1.8%)	0 (0.0%)	8 (2.7%)	
4.	Somewhat fertile	75 (63.0%)	7 (6.1%)	14 (23.3%)	96 (32.8%)	

Agricultural cropping practices

We found that the around 68% of the farmers followed the both cropping practices i.e., mono-cropping and mixed cropping. In the case of the Gulmi and Mustang districts very few numbers of the farmers follow the sole mono-cropping practices. This shows that the farming practices followed by the farmers in the research areas shows the potentiality to increase the crop diversification which helps to conserve the ecosystem services.

Table 40. Cropping practices followed by the farmers in the project districts

S. N	Cropping practices	Dang	Gulmi	Mustang	Total	P value
1.	Mono cropping	26 (21.8%)	0 (0.0%)	3 (5.0%)	29 (9.9%)	< 0.001
2.	Mixed cropping	13 (11.0%)	29 (25.4%)	21 (35.0%)	63 (21.5%)	
3.	Both	80 (67.2%)	84 (73.7%)	34 (56.7%)	198 (67.6%)	

Nutrients management

The results shows that the overall the more than 90% of the farmers use the compost for the nutrients management in all three districts. The use of the chemical fertilizers also contributes more than 50% in the nutrients management practices. The use of the green manure and cover crops for the nutrients management was not found in practices by the farmers in the study areas but the farmers in the mustang used cover crops as a practice. We concluded that the agricultural practices could be changed incorporating the different nutrients management practices for the nutrients management in the study districts.

Table 41. Nutrient management practices adopted by the farmers in the project districts

SN	Nutrients management	Dang	Gulmi	Mustang	Total	P value
1.	Compost					
	Yes	117 (98.3%)	99 (86.8%)	54 (90.0%)	270 (92.2%)	< 0.001
	No	2 (1.7%)	15 (13.2%)	6 (10.0%)	23 (7.8%)	
2.	Chemical fertilizers					
	Yes	79 (66.4%)	66 (57.9%)	30 (50.0%)	175 (59.7%)	< 0.001
	No	40 (33.6%)	48 (42.1%)	30 (50.0%)	118 (40.3%)	

3.	Green manure					
	Yes	2 (1.7%)	0 (0.0%)	3 (5.0%)	5 (1.7%)	0.053
	No	117 (98.3%)	114 (100.0%)	57 (95.0%)	288 (98.3%)	
4.	Cover crops					
	Yes	1 (0.8%)	0 (0.0%)	19 (31.7%)	20 (6.8%)	< 0.001
	No	118 (99.2%)	114 (100.0%)	41 (68.3%)	273 (93.2%)	
5.	Mulching					
	Yes	109 (91.6%)	114 (100.0%)	58 (96.7%)	281 (95.9%)	0.005
	No	10 (8.4%)	0 (0.0%)	2 (3.3%)	12 (4.1%)	
6.	Conservation tillage					
	Yes	0 (0.0%)	0 (0.0%)	44 (73.3%)	44 (15.0%)	< 0.001
	No	119 (100.0%)	114 (100.0%)	16 (26.7%)	249 (85.0%)	
7.	Others practices					
	Yes	10 (8.4%)	0 (0.0%)	1 (1.7%)	11 (3.8%)	0.002
	No	109 (91.6%)	114 (100.0%)	59 (98.3%)	282 (96.2%)	

Soil analysis

Crop production and its yield is a function of four major factors, i.e. yield = f (crop, soil, climate and management). Fertilizer recommendation therefore varies with crop cultivar, specific site of cultivation, temperature variability and required necessary inputs of crop production). For this, soil testing and analysis are interpreted like low, to very high which is easily understood by the growers.

Soil pH

Hydrogen ions present in the soil decide pH value of the soil. It is a measure of the acidity or basicity in soils, which affects the availability of plant nutrients. Soil pH status and values of soil sample analyses are presented in Tables 1a (Dang, 1b$_{1-3}$ (Gulmi) and 1c$_{1-3}$ (Marpha). which in general reflects that the samples were acidic in nature in Dang, moderately acidic to neutral in Gulmi and neutral to basic in Marpha. Table 2a (Dang, 2b$_{1-3}$ (Gulmi) and 2c$_{1-3}$ (Marpha) represents the statistical values (minimum, maximum, standard deviation and mean) of sampled sites.

Table 42. Soil pH ststus of districts project sites

(Soil pH status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020)

SN	Soil pH	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Acidic	21	91.00	20	100.00	24	96
2	Neutral	2	9.00	0	0.00	1	4

(Soil pH status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	2	9.52	3	14.29	2	9.52
2	Neutral	19	90.48	18	85.71	19	90.48

(Soil pH status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	10	58.82	12	70.59	11	64.71
2	Acidic	1	5.88	0	0.00	1	5.88
3	Neutral	6	35.30	5	29.41	5	29.41

(Soil pH status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Mod. Acidic	5	31.25	4	25.00	6	37.50
2	Neutral	11	68.75	12	75.00	9	56.25
3	Basic	0	0.00	0	0.00	1	6.25

(Soil pH status of Gharapjing sampled sites, Marpha, 2020 (N=6)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Basic	6	100.00	6	100.00	6	100.00

(Soil pH status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Basic	6	100.00	6	100.00	6	100.00

(Soil pH status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Soil pH	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Neutral	1	10.00	0	0.00	0	0.00
2	Basic	9	90.00	10	100.00	10	100.00

(Soil pH values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	5.10	4.70	4.80
2	Maximum	6.50	6.30	6.50
3	Standard deviation	0.40	0.46	0.34
4	Average	5.94	5.83	5.47

(Soil pH status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	6.40	6.40	6.40
2	Maximum	7.40	7.40	7.40

3	Standard deviation	0.29	0.32	0.32
4	Average	6.98	7.01	6.97

(Soil pH status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	5.10	5.60	5.20
2	Maximum	7.40	7.50	7.50
3	Standard deviation	0.59	0.52	0.60
4	Average	6.41	6.41	6.26

(Soil pH status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	6.30	6.40	6.20
2	Maximum	7.40	7.30	7.60
3	Standard deviation	0.38	0.29	0.38
4	Average	6.79	6.81	6.78

(Soil pH status of Gharapjing sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	8.20	8.30	8.20
2	Maximum	8.50	8.40	8.50
3	Standard deviation	0.10	0.05	0.1
4	Average	8.33	8.33	8.37

(Soil pH status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	8.20	7.90	7.90
2	Maximum	8.50	8.50	8.50
3	Standard deviation	0.13	0.22	0.22
4	Average	8.32	8.32	8.32

(Soil pH status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	7.50	8.00	7.60
2	Maximum	8.60	8.90	8.80
3	Standard deviation	0.37	0.26	0.36
4	Average	8.27	8.5	8.44

Soil OM and C

OM is a measure of use of FYM and OC as measure of organic matter available in the soil, and the C:N ratio (carbon present in the soil to the ration of nitrogen present in the soil) lying in favorable range >2% and <30% for bacteria growing properly within this limit. The analyses of soil samples of the sampled sites in three districts are presented in Table 3a (Dang), $3b_{1-3}$ (Gulmi) and $3c_{1-3}$ (Marpha). Findings showed that over 80% samples with medium level of OM in Dang, which was slightly better in majority of the surveyed farmers of Sunapani VDC than other two VDCs. It was very low to low in Gulmi, and low to very high in Marpha, respectively. Respective statistical values of three survey districts are given in Table 4a (Dang), $4b_{1-3}$ (Gulmi) and $4c_{1-3}$ (Marpha).

Table 43. Soil OM status of districts project sites

(Soil OM status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	OM	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	8.70	0	0.00	4	16.00
2	Medium	21	91.30	19	95.00	20	80.00
3	High	0	0.00	1	5.00	1	4.00

(Soil OM status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	5	23.81	6	28.57	3	14.29
2	Low	16	76.19	15	71.43	18	85.71

(Soil OM status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	10	58.82	9	52.94	10	58.82
2	Low	7	41.18	8	47.06	7	41.18

(Soil OM status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	12.50	4	25.00	4	25.00
2	Low	14	87.50	12	75.00	12	75.00

(Soil OM status of Gharapjomg sampled sites, Marpha, 2020 (N=6)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	High	2	33.33	2	33.33	1	16.67
2	Very High	4	66.67	4	66.67	5	83.33

(Soil OM status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	0	0.00	3	50.00	3	50.00
2	High	5	83.33	3	50.00	3	50.00
3	Very High	1	16.67	0	0.00	0	0.00

(Soil OM status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	OM	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	3	30.00	0	0.00	0	0.00
2	Medium	1	10.00	2	20.00	2	20.00
3	High	4	40.00	4	40.00	6	60.00
4	Very High	2	20.00	4	40.00	2	20.00

(Soil OM and C values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	2.33	1.35	2.54	1.47	1.42	0.82
2	Maximum	4.79	2.78	5.24	3.04	6.17	3.58
3	Standard deviation	0.70	0.41	0.63	0.37	1.15	0.67
4	Average	3.48	2.02	3.71	2.15	3.51	2.03

(Soil OM and C values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.83	0.48	0.70	0.40	0.70	0.40
2	Maximum	2.15	1.25	1.89	1.10	2.09	1.21
3	Standard deviation	0.35	0.20	0.36	0.21	0.35	0.20
4	Average	1.25	0.73	1.25	0.73	1.33	0.77

(Soil OM and C values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.56	0.33	0.50	0.29	0.70	0.40
2	Maximum	1.56	0.90	1.49	0.86	1.89	1.10
3	Standard deviation	0.26	0.15	0.32	0.19	0.37	0.21
4	Average	0.98	0.57	0.98	0.57	1.09	0.63

(Soil OM and C values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	0.83	0.48	0.43	0.25	0.50	0.29
2	Maximum	1.76	1.02	2.49	1.44	1.69	0.98
3	Standard deviation	0.23	0.13	0.45	0.26	0.32	0.18
4	Average	1.21	0.70	1.20	0.69	1.17	0.68

(Soil OM and C values of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	9.26	5.37	9.12	5.29	1.59	0.92
2	Maximum	14.47	8.39	14.90	8.64	11.29	6.55
3	Standard deviation	1.79	1.04	2.15	1.25	3.64	2.11
4	Average	11.08	6.43	11.34	6.57	8.97	5.20

(Soil OM and C values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	5.64	3.27	3.04	1.76	3.18	1.84
2	Maximum	11.43	6.63	9.26	5.37	7.96	4.62
3	Standard deviation	2.10	1.22	2.30	1.34	2.01	1.16
4	Average	7.45	4.32	5.75	3.33	5.50	3.19

(Soil OM and C values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm		15-30 cm		30-60 cm	
		OM	Carbon	OM	Carbon	OM	Carbon
1	Minimum	2.46	1.43	2.75	1.60	2.89	1.68
2	Maximum	15.92	9.23	24.60	14.27	14.61	8.47
3	Standard deviation	4.49	2.61	7.18	4.16	3.83	2.22
4	Average	6.90	4.00	10.81	6.27	7.44	4.31

To predict nutrient need of crops soil test is performed and calibrated against the response of crops, and thus interpretation and evaluation of the soil test values primarily form the basis for fertilizer recommendations especially major nutrients; like N, P, K.

Soil N

Nitrogen is an essential constituent of amino acids, nucleic acids, nucleotides and chlorophyll; and it promotes rapid plant growth. Both NH4+ and NO3- forms can be taken up and metabolized by plants. Soil sample analyses showing soil N status and N values of Dang, Gulmi and Marpha are presented in Table 5-6a (Dang), 5-6b$_{1-3}$ (Gulmi) and 5-6c$_{1-3}$ (Marpha). The findings of soil sample analysis indicates that the values range low-high in Dang, low-medium in Gulmi and low- high in Marpha sample sites.

Table 44. Soil N status of districts project sites

(Soil N status of Ragaija, Sunepani and Baghmare sampled sites, Dang, 2020

SN	N	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	-	-	-	-	2	8.00
2	Medium	18	78.26	13	65.00	12	48.00
3	High	5	21.74	7	35.00	11	44.00

(Soil N status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	20	95.24	21	100.00	21	100.00
2	Medium	1	4.76	0	0.00	0	0.00

(Soil N status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	17	100.00	17	100.00	17	100.00

(Soil N status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	16	100.00	15	93.75	16	100.00
2	Medium	-	00.00	1	6.25	-	00.00

(Soil N status of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	0	0.00	0	0.00	1	6.25
2	High	6	100.00	6	100.00	5	93.75

(Soil N status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	0	0.00	2	33.33	2	33.33
2	High	6	100.00	4	66.67	4	66.67

(Soil N status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	N	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	4	40.00	2	20.00	2	20.00
2	High	6	60.00	8	80.00	8	80.00

(Soil N values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	0.12	0.13	0.07
2	Maximum	0.24	0.26	0.31
3	Standard deviation	0.03	0.03	0.06
4	Average	0.17	0.18	0.18

(Soil N values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.04	0.03	0.03
2	Maximum	0.11	0.09	0.10
3	Standard deviation	0.02	0.02	0.02
4	Average	0.06	0.06	0.07

(Soil N values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.03	0.02	0.03
2	Maximum	0.08	0.07	0.09
3	Standard deviation	0.01	0.02	0.02
4	Average	0.05	0.05	0.05

(Soil N values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.04	0.02	0.02
2	Maximum	0.09	0.12	0.08
3	Standard deviation	0.01	0.02	0.02
4	Average	0.06	0.06	0.06

(Soil N values of Gharapjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.46	0.46	0.08
2	Maximum	0.62	0.75	0.56
3	Standard deviation	0.061	0.11	0.18
4	Average	0.54	0.57	0.45

(Soil N values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.28	0.15	0.16
2	Maximum	0.57	0.46	0.40
3	Standard deviation	0.11	0.12	0.10
4	Average	0.37	0.29	0.27

(Soil N values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	0.12	0.14	0.14
2	Maximum	0.80	1.23	0.79
3	Standard deviation	0.23	0.36	0.20
4	Average	0.35	0.54	0.38

Soil P

Like N, P plays important functions in energy storage and transfer and the maintenance of membrane integrity. Soil P status and P values shows that 88% of the farmers' of Santinagar, 73.9% in Ragauja and 45% in Sunepani VDCs are having low status of P in their fields (Table 7a), among them, the lowest mean P value (20.58 P) was recorded in Santinagar, while the highest P value was obtained in soil samples from Ragauja VDC (Table 8a). Similarly, soil P values ranged very low-very high in Gulmi (Table 7-8b_{1-3}) and low- high in Marpha, low-medium in Pangling and medium- very high in Gharpjong and sampled sites (Table 7-8c_{1-3}). The uptake of phosphorus by the plant occurs in the form of HPO42- and H2PO4- ions from the soil solution. The major functions are. (Gulmi) and 5-6c_{1-3} (Marpha)

Table 45. Soil P status of districts project sites

(Soil P status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	P	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	17	73.91	9	45.00	22	88.00
2	Medium	1	4.35	3	15.00	1	4.00
3	High	5	21.74	8	40.00	2	8.00

(Soil P status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	9.52	1	4.76	3	14.39
2	Low	11	52.38	9	42.86	10	47.62
3	Medium	5	23.81	8	38.10	6	28.57
4	High	1	4.76	2	9.52	1	4.76
5	Very High	2	9.52	1	4.76	1	4.76

(Soil P status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	2	11.76	2	11.76	5	29.41
2	Low	7	41.18	5	29.41	4	23.53
3	Medium	4	23.53	4	23.53	6	35.30

4	High	3	17.65	5	29.41	2	11.76
5	Very High	1	5.88	1	5.88	0	

(Soil P status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	3	18.75	2	12.50	2	12.50
2	Low	7	43.75	7	43.75	4	25.00
3	Medium	2	12.50	2	12.50	6	37.50
4	High	3	18.75	5	31.25	4	25.00
5	Very High	1	6.25	0	0.00	0	0.00

(Soil P status of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Medium	2	33,33	4	66.67	3	50.00
2	High	3	50.00	0	0.00	1	16.67
3	Very High	1	16.67	2	33.33	2	33.33

(Soil P status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	33,33	2	33.33	3	50.00
2	Medium	3	50.00	4	66.67	2	50.00
3	High	1	16.67	0	0.00	1	16.67

(Soil P status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	P	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	4	40.00	3	30.00	3	30.00
2	Medium	6	60.00	7	70.00	7	70.00

(Soil P values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	1.00	4.56	3.00
2	Maximum	582.16	119.58	138.04
3	Standard deviation	152.70	39.49	31.88
4	Average	72.99	51.48	20.58

(Soil P values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	3.38	6.98	1.83
2	Maximum	241.44	122.41	225.99
3	Standard deviation	55.14	29.62	47.51
4	Average	41.51	36.43	35.40

(Soil P values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	5.95	7.50	1.83
2	Maximum	114.68	159.51	96.65
3	Standard deviation	34.89	39.44	29.42
4	Average	41.60	49.33	32.72

(Soil P values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	4.41	1.83	5.44
2	Maximum	124.99	107.98	86.86
3	Standard deviation	33.84	33.91	24.57
4	Average	38.13	40.99	39.87

(Soil P values of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	33.10	33.1	33.10
2	Maximum	136.20	137.2	171.90
3	Standard deviation	40.33	53.5	55.94
4	Average	70.14	67.6	85.15

(Soil P values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	15.80	15.80	15.80
2	Maximum	102.50	50.50	67.80
3	Standard deviation	32.29	13.05	21.93
4	Average	38.90	30.23	33.13

(Soil P values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	15.80	15.80	15.80
2	Maximum	50.50	33.10	33.10
3	Standard deviation	11.70	8.36	8.36
4	Average	27.92	27.91	27.91

Soil K

Soil samples analyses for K status and K value revealed quite different than N and P, i.e. over 80% of the soil samples from Raguaja and Sunepani, and over 95% soil samples from Santinagar VDCs of Dang showing high K status (Table 9-10a), K mean value was also the highest from soil samples of Santinagar. K status ranged low to very high in all three sample sites of Gulmi (Table 9-10b_{1-3}) and Marpha (Table 9-10c_{1-3}). Potassium in the form of the K+ ion can be taken up readily by plant roots from the soil solution. Potassium controls water loss from plants as the K+ ion plays a crucial role in opening and closing of stomata.

Table 46. Soil K status of districts project sites

(Soil K status of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	K	Ragauja (N=23)		Sunepani (N=20)		Santinagar (N=25)	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	-	-	1	5.00	-	-
2	Medium	4	17.39	3	15.00	1	4.00
3	High	19	82.61	16	80.00	24	96.00

(Soil K status of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	1	4.76	1	4.76	2	9.52
2	Low	7	33.33	10	47.62	10	47.62
3	Medium	7	33.33	9	42.86	8	38.10
4	High	5	23.81	0	0.00	0	0.00
5	Very High	1	4.76	1	4.76	1	4.76

(Soil K status of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	0	0.00	1	5.88	1	5.88
2	Medium	10	58.82	13	76.47	13	76.47
3	High	5	29.41	2	11.76	3	16.67
4	Very High	2	11.76	1	5.88	1	5.88

(Soil K status of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	1	6.25	0	0.00	1	6.25
2	Low	2	12.50	5	31.25	5	31.25
3	Medium	9	56.25	9	56.25	8	50.00
4	High	4	25.00	1	6.25	1	6.25
5	Very High	0	0.00	1	6.25	1	6.25

(Soil K status of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	0	0.00	0	0.00	1	16.67
2	Low	2	33.33	3	50.00	4	66.66
3	Medium	4	66.67	2	33.33	1	16.67
4	High	0	0.00	1	16.67	0	0.00

(Soil K status of Marpha sampled sites, Marpha, 2020 (N=6)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Very Low	0	0.00	0	0.00	1	16.67
2	Low	4	66.66	3	50.00	3	50.00
3	Medium	1	16.67	3	50.00	2	33.33
4	Very High	1	16.67	0	0.00	0	0.00

(Soil K status of Pangling sampled sites, Marpha, 2020 (N=10)

SN	K	0-15 cm		15-30 cm		30-60 cm	
		Sample (No)	Percent	Sample (No)	Percent	Sample (No)	Percent
1	Low	2	20.00	5	50.00	4	40.00
2	Medium	6	60.00	3	30.00	5	50.00

3	High	0	0.00	1	10.00	0	0.00
4	Very High	2	20.00	1	10.00	1	10.00

(Soil K values of Ragauja, Sunepani and Santinagar sampled sites, Dang, 2020

SN	Statistical value	Ragauja (N=23)	Sunepani (N=20)	Santinagar (N=25)
1	Minimum	227.58	14.94	233.05
2	Maximum	867.64	841.91	893.65
3	Standard deviation	179.69	195.61	168.99
4	Average	481.23	425.50	596.93

(Soil K values of Balkot sampled sites, Gulmi, 2020 (N=21)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	45.20	33.21	21.22
2	Maximum	602.76	692.69	680.70
3	Standard deviation	147.52	144.92	137.01
4	Average	204.79	145.12	127.71

(Soil K values of Lumcha sampled sites, Gulmi, 2020 (N=17)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	117.15	105.16	51.20
2	Maximum	632.73	572.78	392.93
3	Standard deviation	151.88	123.48	88.84
4	Average	294.18	238.46	196.49

(Soil K values of Pipaldhara sampled sites, Gulmi, 2020 (N=16)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	21.22	57.19	15.23
2	Maximum	494.84	500.84	632.73
3	Standard deviation	133.98	117.82	158.12
4	Average	219.81	188.71	180.85

(Soil K values of Gharpjong sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	98.60	69.10	39.00
2	Maximum	216.90	499.20	211.50
3	Standard deviation	47.25	163.41	57.12
4	Average	150.10	168.08	103.93

(Soil K values of Marpha sampled sites, Marpha, 2020 (N=6)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	55.10	60.50	29.60
2	Maximum	1114.00	232.50	176.10
3	Standard deviation	420.11	62.10	54.56
4	Average	266.52	119.67	97.02

(Soil K values of Pangling sampled sites, Marpha, 2020 (N=10)

SN	Statistical value	0-15 cm	15-30 cm	30-60 cm
1	Minimum	71.20	52.40	60.50
2	Maximum	649.70	663.10	518.50
3	Standard deviation	209.75	198.61	135.30
4	Average	219.76	179.74	170.90

6.2.5 MANAGEMENT STRATEGY

1. Soil physical, chemical and biological indicators of farm soils have been observed in terms of its productive capacity by working on the yield difference between organic and conventional farms. The major quality indicators of soil are presented in Table 11. In this study, the main purpose of the soil sampling is for efficiency of nutrient inputs to maximize crop production and sustain soil fertility.

Soil quality indicators

SN	Soil properties	Indicators
1	**Biological property indicator** (These all together enrich soil and support in all aspects of plant growth and production)	Microbial biomass Carbon Microbial biomass Nitrogen Enzyme activities Soil macro-organisms (arthropods) Soil micro-organisms (pathogens) Earthworms
2	**Chemical property indicator** (These all together support in availability of nutrient, microorganisms activity and plant growth)	Soil pH Soil organic matter content Available Nitrogen Available Phosphorus Available Potassium Cation exchange capacity Micro nutrients (Ca, Mg, Al, Mn, Zn, Br, Na, Fe) Redox potential
3	**Physical property indicator** (These all indicators together support in aeration, mobility of water, root penetration and soil fertility)	Soil texture Soil structure Bulk density Soil porosity Soil color Soil moisture Soil temperature Soil water holding capacity

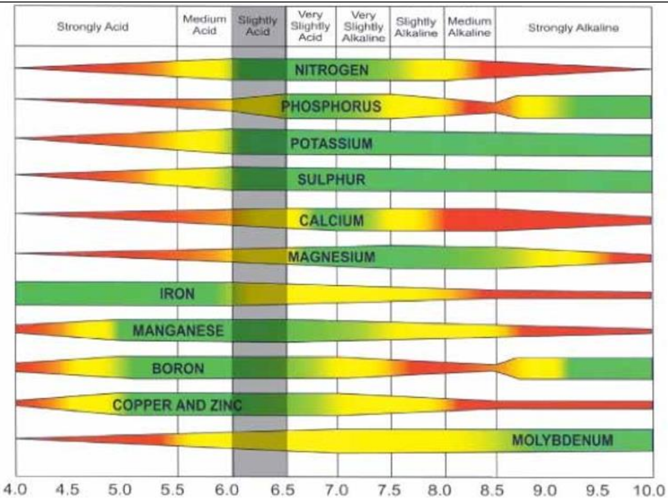
Source: Anukwonke, 2014.

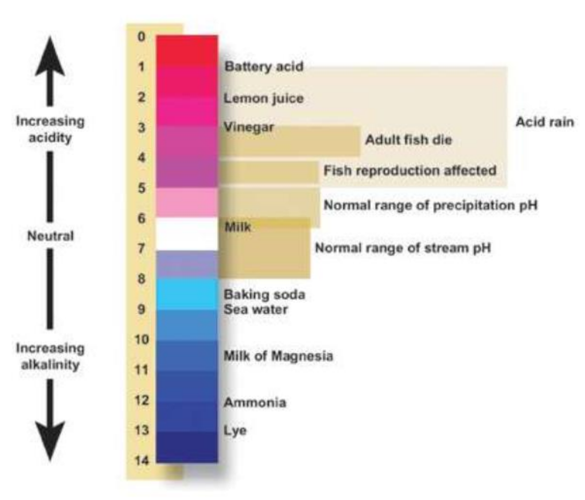
2. The N-P-K in balanced form plays important role in plant growth, crop yield and productivity. Their deficiency in plants are clearly identified by plant deficiency symptoms (Figure 19) and based on soil analyses are recommended in balanced form not to exceed their quantity otherwise may result toxicity to plant and change soil characteristics as well.

Nitrogen (Left: Normal & Right: Deficiency)	Phosphorus (Left: Normal & Right: Deficiency)	Potash (Left: Normal & Right: Deficiency)

Figure 15. Main nutrients (N, P, K) for crop plants showing normal and deficiency symptoms

3. Every farmer has his own management practice, which influences nutrient availability and plant growth. There are also many trace elements, whose deficiency symptoms are expressed by plants, which differ from one field to another, and can be diagnosed in growing plants. The pH neutrality indicates availability of nutrients to plants. In the Figure 20, the gray area depicts a neutral pH of soil, when all nutrients are soluble and mostly available to plants. The pH scale ranges from 0 to 14 with pH 7 as the neural point. So maximum availability of nutrient to plants is the way to rather than just using fertilizers in the crop fields.





Nutrient availability at different pH of soil	pH range 0-14 with different color comparator

Figure 16 Effects of the soil pH on transfer of nutrients from soil to the plants through roots

4. Plant growing in fertile soil is reservoir of nutrients which are essential elements required for plant growth, production and productivity. Their available forms, mass (%) in dry plant tissue and key functions are summarized in Table 47.

Table 47. Fertile soil with reservoir of nutrients essential for plant growth, production and productivity

SN	Element	Form primarily absorbed by plants	Mass (%) in dry tissue	Major functions
	Macronutrients			
1.	Carbon	CO_2	45	Major component of plant's organic compounds
2.	Oxygen	CO_2	45	Major component of plant's organic compounds
3.	Hydrogen	H_2O	6	Major component of plant's organic compounds
4.	Nitrogen	NO_3^-, NH_4^+	1.5	Component of nucleic acids, proteins, hormones, chlorophyll, coenzyme
5.	Potassium	K^+	1	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
6.	Calcium	Ca^{2+}	0.5	Important in formations and stability of cell walls and in maintenance of membrane structure and permeability, activates some enzyme; regulates many responses of cells to stimuli
7.	Magnesium	Mg^{2+}	0.2	Component of chlorophyll; cofactor and activator of many enzymes
8.	Phosphorus	$H_2PO_4^+$, HPO_4^{2-}	0.2	Component of nucleic acids, phospholipids, ATP, several coenzymes
9.	Sulfur	SO_4^{2-}	0.1	Component of proteins, coenzymes
	Micronutrients			

1.	Chlorine	Cl^-	0.01	Requiring for water splitting step of photosynthesis & water balance
2.	Iron	Fe^{3+}, Fe^{2+}	0.01	Components of cytochromes; cofactor of some enzymes, needed for photosynthesis
3.	Manganese	MN^{2+}	0.005	Active in formation of amino acids; activates some enzymes, required for water splitting step of photosynthesis
4.	Boron	$H_2BO_3^-$	0.002	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall formation
5.	Zinc	ZN^{2+}	0.002	Active in formation of chlorophyll; cofactor of some enzymes; needed for DNA transcription
6.	Copper	Cu^+, Cu^{2+}	0.001	Compound of many redox and lignin-biosynthetic enzymes
7.	Nickle	Ni^{2+}	0.001	Cofactor of enzyme functioning in nitrogen metabolism
8.	Molybdenum	MoO_4^{2-}	0.0001	Essential for mutualistic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

Source: Huang et al., 2008.

5. Use of FYM/Poultry manure Vermi-compost is always beneficial to plants and soils in many aspects. This has been exemplified with the use of Vermi-compost and comparing with chemical fertilizers (Table 48).

Table 48. Farm soil properties under vermi-compost and chemical fertilizer

SN	Chemical and biological properties of soil	Vermi-compost	Chemical fertilizers
1.	Availability of nitrogen (kg/ha)	256.0	185.0
2.	Availability of phosphorus (kg/ha)	50.5	28.5
3.	Availability of potash (kg/ha)	489.5	426.5
4.	Azatobacter (1000/gm of soil)	11.7	0.8
5.	Phospho-bacteria (100,000/kg of soil)	8.8	3.2
6.	Carbonic biomass (mg/kg of soil)	273.0	217.0

Source: Suhane, 2007.

6. Effect of climate in agriculture especially in crop production, and pest problems has been realized all over the world. The impacts of climate change on agriculture are listed in Table 49.

Table 49. Climate change impacts on agriculture

SN	Climate event	Possible impact on agriculture
1.	Warmer and fewer cold days and nights	Increased yields in colder environments
2.	Warmer and more frequent hot days and nights over most land areas (virtually certain)	Decreased yields in warmer environments Increased insect pest outbreaks
3.	Warm spells and heat waves increasing in frequency over most land areas (very likely)	Reduced yields in warmer regions due to heat stress Increased crop damage due to wildfire
4.	Heavy precipitation events increasing in frequency over most areas (very likely)	Heavy precipitation events increasing in frequency over most areas (very likely)
5.	Drought-affected area increases (likely)	Increase in land degradation and soil erosion Lower yields from crop damage and failure Increased risk of wildfire, loss of arable land Salinization by irrigation/irrigation water
6.	Intense tropical cyclone activity increases (likely)	Damage to crops, storages, and agricultural infrastructure
7.	Extremely high sea levels increase in incidence (excludes tsunamis) (likely)	Salinization of irrigation water, loss of arable land, and increase in migration

Source: FAO, 2008.

7. Emphasis has been given on improving the use efficiency of fertilizers through the 4R nutrient stewardship principle, i.e., effective use, i) Right source, ii) Right rate, iii) Right time, iv) Right placement. However, important factors for controlling efficiency of fertilizer application are numerous: i). The nature of crop and its variety, ii). Method and time of application of fertilizer, iii). Crop management, iv). Cropping system, v). Chemical composition of soil and its pH, vi). Organic matter content of the soil, vii). Physical condition including drainage, aeration, etc., viii). Weather conditions, ix). Soil moisture, and x). Balance of nutrients. All these have to be taken care for efficient utilization of nutrients.

6.2.6 Recommendations

It has revealed that pH value range more acidic to (Dang) to towards basic (Marpha), soil organic contents variable, slighter better in Sunapani and C:N ratio in higher range, and major nutrients NPK are not in balanced forms as perceived from the study of three district sampled sites.

As general recommendation, one aspect, fertilizers are suggested depending upon the amount of nutrients available in the soil as well as requirement of the crop. For example, i) if available soil nutrients are very low in soil test, then increase the dose of fertilizer by 50%, ii) if available soil nutrients are low, increase the dose of fertilizer by 25%, iii) if available soil nutrients are medium or slightly more than medium, no need to change the fertilizer dose and amount of application, iv) if available soil nutrients are very high, reduce the dose of fertilizer by 50% and v) if available soil nutrients are high, reducing the dose of fertilizer by 25%, etc. However, based on the overall management strategies, the recommendations are made as follows:

- Proper crop selection, reduced tillage practices and crop residue utilization, discarding of tillage sequence that reduces loss of soil or water and disturbance to soil structure.
- Sub-soil improvement with terrace and contour bunds, agroforestry practices, levelling or horizontal strip constructed in crop field prevent accelerated erosion.
- Agronomic practices- cropping systems-mulching, alley cropping, contour cropping, timely planting, continuous cropping with well-managed crop residue, zero or minimum tillage and with legume-based and other crop rotations, legume plow down (green manure), cover crops, forage increase soil organic matters and soil microbial biomass.
- Fertility management- Soil test-based recommendation, balanced use of fertilizers, organic matter application, cropping systems, green manuring,
- Water management- Minimizing water loss, sprinkler irrigation, drip irrigation, mulching to reduce soil moisture loss and maintain temperature,
- Pest management- Following eco-friendly and bio-rational practices including IPM, INM, ISPM etc. for crop specific important pests of commercial crop cultivation. INM system is the maintaining or adjusting plant nutrient supply to achieve a given level of crop production by

optimizing the benefits from all possible sources of plant nutrients for sustainable crop production. Application of recommended dose of N-P-K @ 200-44-82 kg ha-1 plus either FYM at 5 Mg ha-1 or Vermi-compost at 3 Mg ha-1 was the best technology for harvesting higher yield of cauliflower with its quality produce and maintaining ecological health (Batabyal et al., 2016).

- Organic farming- It relies upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic waste, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests.
- Among different climatic factors, rainfall and temperature are the most dominating ones influencing nutrient leaching from soil. Use of slow-release fertilizer is an important approach to reduce nutrient leaching. Further, reclamation of alkali soil using recommended dose of gypsum and acidic soil using lime.
- Farmers' field experimentation is important to determine the type and amount of fertilizers to suit particular soil type and crop. Improved timing and/or splitting of fertilizer N increased N recovery efficiency from 0.17 kg kg-1 in FFP plots to 0.27 kg kg-1 in Site Specific Nutrient Management plots with 63% greater agronomic N use efficiency compared to Farmer Field Practice (Khurana et al., 2008).
- The effects of trace elements on *Brassica napus* studied shows that trace element- 2 and 4 mMK2SiO used in salinity, 300 mMNaCl increased leaf area, leaf fresh weight, seed yield, and photosynthesis; also increased APX and NR activities and chl content. Similarly, 15 and 30g L-1 as Na2SeO3 used in drought, limited irrigation at early stem elongation increased plant height, pod and seed development and yield (Hasanuzzaman et al., 2020).
- Nanotechnology is showing promise and may help improve the nutrient efficiency. Nanofertilizers release the nutrients in a controlled manner in response to reaction to different signals such as heat, moisture, etc. For example, Titanium dioxide (TiO2) increased the light absorption and chlorophyll content in the plant, while zinc oxide nanoparticles had a twin role of being an essential nutrient and a cofactor for nutrient-mobilizing enzymes. With these the tomato plants were better able to absorb light and minerals producing nearly 82% (by weight) more fruit than untreated plants, and the fruit had higher antioxidant (lycopene) content.

Hence, it is necessary to know the real field and crop situation by frequently visiting crop fields, sampling and monitoring plants, identifying deficiency symptoms, plant growth and vigor, crop yield and quality, and recommended best eco-friendly practices for higher crop productivity with long-term sustaining of soil productivity.

6.2.7 Information sharing

The technical support on strengthening agro-ecosystems resilience for climate change adaptation to improve food and nutrition security was implemented and information gathered from field situations in three project districts in the midst of the challenges posed by the onset of COVID-19 pandemics. Because of time-to-time lockdown due to pandemics, field movements were restricted which affected field activities and information gathering during crop growing seasons. However, in close coordination with all stakeholders, necessary activities were performed, no cost time extension was approved, necessary reports prepared and shared with FAO, University, Government and concerned stakeholders. Final information sharing meeting (gathering) was also decided in consultation with concerned stakeholders to share findings of the study

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