Study Guide
BS Rural Development

BASIC AGRICULTURE

COURSE CODE: 7903



Department of Agricultural Sciences
ALLAMA IQBAL OPEN UNIVERSITY

BASIC AGRICULTURE

STUDY GUIDE

COURSE CODE: 7903 **UNIT: 1-9**

DEPATMENT OF AGRICULTURAL SCIENCES
ALLAMA IQBAL OPEN UNIVERSITY
ISLAMABAD

COURSE TEAM

Chairman Course Team:

Prof. Dr. Sher Muhammad
Chairman
Department of Agricultural Sceinces, AIOU

Compiled by:

Dr. Muhammad Shaukat
Department of Agricultural Sciences, AIOU
Dr. Muhammad Rehan
Department of Agronomy, Ghazi University, Dera Ghazi Khan
Dr. Riffat Sultana
Department of Agronomy, Ghazi University, Dera Ghazi Khan
Mr. Tauqeer Qadir
Research Assistant, Reham Yar Khan Sugarcane Research Institute

Reviewer:

Dr. Sabir Hussain Shah
Department of Agricultural Sciences, AIOU
Muhammad Fahd Bhatti
Department of Agricultural Sciences, AIOU

Editor:

Mr. Fazal Karim
Directorate of Academic Planning & Course Production (AP&CP)
Allama Iqbal Open University
H-8, Islamabad

PREFACE

Agriculture forms the back bone of Pakistan's economy and is also mainstay for a significant share of its population. Unless students have strong understanding of agricultural basics, they will not be able to realize the significance of agriculture in food security, rural development and national economy. This Basic Agriculture course is made to ensure that students receive the full knowledge of what agriculture is, its principles and its associated resources and systems in Pakistan.

Department of agricultural sciences (DAS) at AIOU is disseminating the technical knowledge to the young blood on various aspects of agriculture discipline. It is a great need of the hour to impart agricultural education for our graduate students so that they are trained in growing of variety of main crops, feeding livestock and bird rearing. It is necessary to compelled to implement education for agricultural studies of the country. These agri-graduates would be valuable assest for the country to grow sufficient food on large scale to fulfil basic-necessity of ever increasing population of Pakistan.

The eduction on basics of agricultural sciences will give students a straightforward, organized and efficient training about agriculture and basic principle of crop production. The objective of this course is to provide invaluable insights on basics of agriculture to enrolled students and to help them for understanding the relationship between natural resources, farming systems, and economic development.

This course is intended for students at the secondary, intermediate, diploma, or introductory undergraduate level as well a general guide to be beneficial for teachers and extension workers. It is also expected that the knowledge imparted from this course would create awareness and understanding for agriculture, attitude to development of agribusiness and motivate students to contribute to value added agricultural development.

Prof. Dr. Nasir Mahmood
Vice Chancellor

INTRODUCTION OF COURSE

The course content has been organized into nine units, arranged in a logical sequence to facilitate progressive learning. The opening unit introduces the **background of agriculture**, offering students an understanding of its origin, evolution, and importance. This is followed by a unit on the **branches and allied sciences of agriculture**, which familiarizes learners with the multidisciplinary nature of the field and its scientific foundations.

Subsequent units address the **salient features and major problems of Pakistan's agriculture**, enabling students to critically examine current challenges and identify potential solutions. The inclusion of units on **climate, weather, seasons, land, and water resources of Pakistan** emphasizes the environmental factors that directly influence agricultural productivity and sustainability. These units help students appreciate the importance of natural resource management in the agricultural sector.

The course also covers essential technical aspects such as **crop nutrition**, highlighting soil fertility, nutrient requirements, and balanced fertilizer use. To enhance regional understanding, the unit on **agro-ecological zones of Pakistan** explains how variations in climate, soils, and topography affect cropping patterns and farming practices. The unit on **farming systems of Pakistan** provides insight into traditional and modern farming approaches, while the final unit on **agro-based industries** underscores the importance of value addition, processing, and linkages between agriculture and industry.

The authors and compilers acknowledge the contributions of educators, researchers, and institutions whose work has informed the preparation of this course. Constructive feedback from teachers and students is welcomed for the continuous improvement of future editions.

Prof. Dr. Sher Muhammad
Chairman
Department of Agricultural Sciences

ACKNOWLEDGEMENT

The successful development of this course on Basic Agriculture would not have been possible without the valuable contributions, guidance, and support of many individuals and institutions. As Course Coordinator, I would like to express my sincere gratitude to all those who played a role in the planning, development, and completion of this course.

I am deeply thankful to the subject specialists, curriculum developers, and reviewers whose expertise and constructive feedback helped shape the course content and ensured its academic relevance and clarity. Their insights were instrumental in aligning the course with contemporary agricultural practices and the educational needs of students.

I would also like to acknowledge the support and encouragement provided by the academic administration and members of the Board of Studies, whose guidance ensured that the course meets institutional and national curriculum standards. Special appreciation is extended to the teachers and educators who shared their practical experiences and suggestions, contributing to the practical orientation of the course.

Gratitude is also due to researchers, authors, and institutions whose published work served as valuable reference material during the preparation of this course. Their contributions to the field of agriculture have greatly enriched the academic foundation of this course.

Finally, I extend my sincere thanks to all those who contributed directly or indirectly to the successful completion of this course. Any shortcomings or errors remain the sole responsibility of the Course Coordinator. Constructive feedback from teachers and students will be welcomed for the improvement of future editions.

Dr. Muhammad Shaukat
Course Coordinator
Basic Agriculture Course

MAIN OBJECTIVES OF THE COURSE

The main objectives of this course on Basic Agriculture are to:

1. Provide foundational knowledge of agriculture by introducing students to the origin, development, and importance of agriculture in human civilization, with particular reference to Pakistan.
2. Familiarize students with the branches and allied sciences of agriculture, enabling them to understand the multidisciplinary nature of agriculture and its relationship with biological, physical, and social sciences.
3. Develop an understanding of Pakistan's agricultural system, including its salient features, major constraints, and challenges affecting productivity, sustainability, and rural livelihoods.
4. Enhance awareness of climatic and environmental factors by explaining the role of climate, weather, and seasons in influencing agricultural production and farming practices in Pakistan.
5. Build knowledge of land and water resources and their efficient and sustainable use for agricultural development in Pakistan.
6. Introduce the principles of crop nutrition, soil fertility, and nutrient management to promote sustainable crop production.
7. Explain the agro-ecological zones of Pakistan and their impact on cropping patterns, crop adaptation, and regional farming practices.
8. Provide insight into farming systems of Pakistan, including traditional and modern approaches, to help students understand integrated and sustainable farming practices.
9. Highlight the importance of agro-based industries, value addition, and agribusiness in strengthening the national economy and generating employment.
10. Develop analytical and problem-solving skills related to agricultural issues, encouraging students to apply basic agricultural knowledge to real-life situations.
11. Promote awareness of sustainable agriculture and resource conservation, fostering responsible attitudes toward land, water, and environmental stewardship.
12. Prepare students for further studies and careers in agriculture and allied fields, as well as informed participation in agricultural development at the community and national levels.

CONTENTS

Unit #	Title	Page #
1	Background of Agriculture	1
2	Branches and Allied Sciences in Agriculture	9
3	Salient Features and Problems of Pakistan's Agriculture	23
4	Climate, Weather and Seasons of Pakistan	45
5	Land and Water Resources of Pakistan	53
6	Crop Nutrition	69
7	Agro-Ecological Zones of Pakistan	89
8	Farming Systems of Pakistan	113
9	Agro-based Industries of Pakistan	143

Unit:1

BACKGROUND OF AGRICULTURE

Compiled by: Dr. Muhammad Shaukat
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

INTRODUCTION 3
OBJECTIVES : 3
LEARNING OUTCOMES: 3
Agriculture 4
1.1 Introduction 4
1.2. History of Agriculture 4
1.2.1 Early Beginnings 4
1.2.2 Ancient Agricultural Civilizations 5
1.2.3 The Middle Ages and Innovations 5
1.2.4 The Agricultural Revolution (16th–18th Century) 5
1.2.5 The Industrial Age and Mechanization 6
1.2.6 The Green Revolution 6
1.2.7 Modern Agriculture and Sustainability 6
1.3 Importance of Agriculture 7
1.4 Self-Assessment Questions 8
1.5 References 8

INTRODUCTION

In this unit, the student will learn about the history of agriculture in Pakistan and its development with passage of time. Student will know about the major crops of Pakistan, their seasons and their role in Pakistan's economy. The history of agriculture in this region reflects the hard work, traditions, and innovations of farmers over centuries. Even today, agriculture provides food, raw materials for industries, and employment to a large part of the population. It also contributes significantly to the national income and trade of the country. Understanding the history and importance of agriculture in Pakistan helps students to value the efforts of our farmers, recognize agriculture's role in development, and learn ways to make it more sustainable for the future.

OBJECTIVES :

After going through this unit, the students will be able to:

1. Provide students with an understanding of the historical development of agriculture in Pakistan.
2. Highlight the importance of agriculture as the backbone of Pakistan's economy and society.
3. Familiarize students with the major crops, regions, and farming systems in the country.
4. Explain the contribution of agriculture to food supply, employment, and industry.
5. Create awareness about the challenges and issues faced by the agricultural sector.
6. Develop a sense of appreciation for the role of farmers in national growth.
7. Encourage students to think about modern and sustainable practices.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. Explain the historical background of agriculture in the region, from the Indus Valley Civilization to present-day Pakistan.
2. Describe the role of agriculture in Pakistan's economy, society, and culture.
3. Identify the major crops and farming systems practiced in different parts of the country.
4. Analyze the contribution of agriculture to food security, employment, and industrial development.

Agriculture

1.1 Introduction

Agriculture is defined as a science, art and business of growing crops, raising animals and rearing birds in order to meet food, feed and shelter for people. In simple words, agriculture is the cultivation of land for growing of crops and feeding livestock. Agriculture provides fruits, vegetables, grains, milk, meat and clothing such as cotton and wool.

Farmers use land, water, and machines to produce crops and take care of animals. Agriculture is important today as it feeds people across the world. Agriculture includes the crop sector, animal sector, the fishery and poultry sector, the forest sector etc. In the crop sector, wheat, rice, cotton and sugarcane are major crops that are being grown in Pakistan. There are four seasons of growing crops: rabi, zaid rabi, kharif and zaid kharif.

The Rabi season starts from October to December, and it ends in March to May. The major crops of the rabi season are wheat, oat, barley, lentil and chickpea. Kharif season starts from March to July and it ends in October to November. Major crops of the kharif season are rice, cotton, sorghum, millet and maize. Zaid Rabi season starts from the month of February, and it ends in May-June. The major crop of this season is tobacco. Zaid kharif season starts in the month of September and it ends in December-January. The major crop of this season is toria.

Activity 01: Make a table of average temperature and monthly rainfall of the months of the Rabi season of last year..

1.2. History of Agriculture

Agriculture is one of the most significant milestones in human civilization, shaping societies, economies, and cultures for thousands of years. Its history reflects humanity's gradual shift from nomadic hunting and gathering to the establishment of permanent settlements and complex civilizations. The origins of agriculture date back over 10,000 years, during the Neolithic Revolution, when humans first began cultivating plants and domesticating animals. This transformation not only ensured a more reliable food supply but also laid the foundation for population growth, technological advancement, and the rise of nations (Barker, 2009).

1.2.1 Early Beginnings

The first evidence of systematic agriculture can be traced to the Fertile Crescent, a region in the Middle East covering modern-day Iraq, Syria, Lebanon, Israel, and parts of Turkey. Around 9000-7000 BCE, people began cultivating crops such as wheat, barley, lentils, and peas. At the same time, animals like sheep, goats, and cattle were domesticated for food, milk, hides, and labor. This gradual transition

from wild harvesting to controlled cultivation was revolutionary because it allowed communities to produce surplus food, which in turn supported the growth of permanent villages. Agriculture also emerged independently in other parts of the world: rice was domesticated in China around 7000 BCE, maize (corn) in Mesoamerica by 5000 BCE, potatoes in the Andes, sorghum and millet in Africa, and rice along with pulses in the Indus Valley. These regional developments reflect how agriculture arose as a response to both environmental opportunities and human ingenuity (Harris, 2012).

1.2.2 Ancient Agricultural Civilizations

As agriculture advanced, it became the backbone of the great ancient civilizations. In Mesopotamia, sophisticated irrigation systems were developed along the Tigris and Euphrates rivers, allowing farmers to grow crops in arid regions. The Egyptians relied on the annual flooding of the Nile River, which deposited nutrient-rich silt and made the surrounding lands highly fertile. In the Indus Valley (modern-day Pakistan and India), farmers cultivated wheat, barley, and cotton while managing extensive water systems. Meanwhile, in China, rice paddies and millet fields supported growing populations, while the use of silkworms and mulberry cultivation gave rise to the silk industry. Across the Americas, the Maya, Aztec, and Inca civilizations thrived on maize, beans, squash, and potatoes, using terrace farming and chinampas (floating gardens) to maximize productivity. These agricultural systems not only ensured survival but also sustained cultural, political, and economic growth (Bogucki, 2019).

1.2.3 The Middle Ages and Innovations

During the Middle Ages, agriculture evolved further, especially in Europe and Asia. The introduction of the heavy plow, the three-field system, and crop rotation improved soil fertility and yields. Feudal societies were structured largely around agricultural labor, with peasants working lands owned by nobility. In the Islamic Golden Age, scholars introduced new irrigation techniques, brought crops like sugarcane, citrus fruits, and cotton to new regions, and spread agricultural knowledge across North Africa, Spain, and the Middle East. In Asia, rice cultivation in paddy fields became more sophisticated, sustaining dense populations in China, Japan, and Southeast Asia. During this period, agriculture was not only about food but also about trade. Crops such as spices, silk, and cotton played central roles in global commerce.

1.2.4 The Agricultural Revolution (16th–18th Century)

The period between the 16th and 18th centuries marked a turning point often called the Agricultural Revolution in Europe. The introduction of new crops from the Americas, such as maize, potatoes, and tomatoes, significantly diversified diets and improved food security worldwide. Advances in farming techniques, including crop rotation with legumes, selective breeding of animals, and improved

plowing equipment, boosted productivity. Enclosure movements in England consolidated small farms into larger units, increasing efficiency but also displacing many rural workers. This period also witnessed the spread of plantations in colonies, where crops like sugarcane, tobacco, and cotton were grown on a massive scale, often relying on enslaved labor. These changes helped set the stage for the Industrial Revolution by providing both surplus food and raw materials for emerging industries (Moore, 2014).

1.2.5 The Industrial Age and Mechanization

The 19th and early 20th centuries saw rapid progress in agricultural practices driven by industrialization. The invention of machines such as the mechanical seed drill, reapers, threshers, and tractors transformed farming from labor-intensive work into a more efficient system. Railroads and steamships allowed surplus crops to be transported across continents, linking farmers to global markets. Chemical fertilizers and pesticides were developed, significantly increasing yields but also introducing environmental challenges. In many countries, government policies and land reforms aimed to modernize agriculture, while in colonized regions, traditional farming systems were often disrupted and restructured to serve global trade demands. This era marked the beginning of large-scale, mechanized farming that could support urban populations growing rapidly due to industrialization (Prasad et al. 2016).

1.2.6 The Green Revolution

In the mid-20th century, the Green Revolution reshaped global agriculture, especially in developing countries. Led by scientists like Norman Borlaug, high-yielding varieties (HYVs) of wheat, rice, and maize were introduced, along with chemical fertilizers, pesticides, and irrigation systems. Countries like India, Pakistan, and Mexico saw dramatic increases in food production, helping to reduce famines and feed growing populations. However, the Green Revolution also had drawbacks, including environmental degradation, soil nutrient depletion, and increased dependence on chemical inputs. While it improved global food security, it raised concerns about sustainability and equity, as small farmers often struggled to afford the new technologies (Borlaug, 2002).

1.2.7 Modern Agriculture and Sustainability

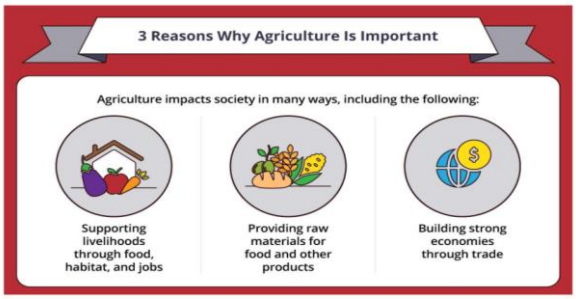
Today, agriculture stands at a crossroads between technological innovation and environmental responsibility. Advances in biotechnology, genetic engineering, precision farming, and digital agriculture are revolutionizing how food is produced. Crops can now be engineered for higher yields, pest resistance, and climate resilience. Drones, sensors, and satellite imaging allow farmers to monitor crops with unprecedented accuracy. At the same time, organic farming, agroecology, and sustainable practices are gaining importance as societies recognize the need to balance productivity with environmental conservation.

Issues such as soil degradation, water scarcity, climate change, and biodiversity loss challenge the future of agriculture, making sustainability a global priority. Furthermore, the concept of urban farming, vertical farming, and controlled environment agriculture is reshaping how food is produced in growing cities (Rehman et al. 2016).

The history of agriculture is the story of human progress, how societies transformed landscapes, developed technologies, and built civilizations on the foundation of food production. From the first domesticated wheat grains in the Fertile Crescent to today's genetically edited crops and precision farming, agriculture has continuously adapted to human needs and environmental challenges. As we move into the future, the lessons of history remind us that agriculture must remain not only a source of sustenance but also a force for sustainability, equity, and harmony with nature.

1.3 Importance of Agriculture

Agriculture impacts society in many ways, including: supporting livelihoods through food, habitat, and jobs; providing raw materials for food and other products; and building strong economies through trade. There are some reasons why agriculture is important.



For thousands of years, agriculture has played an important role in everyday life. Before agriculture, hunting and gathering enabled humans to survive. It wasn't until the transition to the planned sowing and harvesting of crops that humans began to thrive. Humans developed tools and practices to improve agricultural output with more efficient means of sustaining themselves. From there, innovations that created industries led to the modern era.

Today, the importance of agriculture in everyday life can't be minimized. Without the agriculture sector, activities such as getting dressed for work and cleaning the home wouldn't be possible.

- **Shelter**. Wood and plant-based materials, such as bamboo, can be used for indoor décor and construction materials.
- **Morning routine.** Mint is often an ingredient in toothpaste, adding flavor while brushing your teeth, and the caffeine in coffee that keeps you awake is derived from the coffee bean.

• **Dressing up.** In addition to cotton, clothing can be manufactured from hemp, ramie, and flax. Bio-based materials can be used to produce grooming products such as skin creams and shampoos.

• **Cleaning.** Two types of chemicals used in detergents, cleaning products, and bath or hand soap — surfactants and solvents — can be produced from biomass.

• **Driving to work.** Plants make it possible to get to and from work. Think of rubber (sourced from rubber trees) and biodiesel fuel, which often includes ethanol (sourced from corn).

• **Entertainment.** Paper from trees enables you to write, and some musical instruments, such as reed instruments, require materials made from plants.

• **Education.** From pencils (still often made of wood) to paper textbooks, students rely on agricultural products every day.

1.4 Self-Assessment Questions

1. Farmers use _____, water, and machines to produce crops and take care of animals.
2. Rabi season starts from _____.
3. The origins of agriculture date back over _____years.
4. Rice was domesticated in _____ around 7000 BCE.
5. Green Revolution was led by_____.

Answers

1. land **2.** October to December **3.** 10,000 **4**. China **5.** Norman Borlaug

1.5 References

1. Barker, G. (2009). *The agricultural revolution in prehistory: why did foragers become farmers?*. Oxford University Press.
2. Bogucki, P. (2019). Geography and Chronology of the Transition to Agriculture. In *Oxford Research Encyclopedia of Environmental Science*.
3. Borlaug, N. E. (2002). *The green revolution revisited and the road ahead*. Stockholm: Nobelprize. org.
4. Harris, D. R. (2012). Origins and spread of agriculture. In *The cultural history of plants* (pp. 19-32). Routledge.
5. Moore, A. M. (2014). The transition from foraging to farming in Southwest Asia: Present problems and future directions. In *Foraging and Farming* (pp. 620-631). Routledge.
6. Prasad, R., Shivay, Y. S., & Nene, Y. L. (2016). Asia's Contribution to the Evolution of Agriculture: Creativity, History, and Mythology. *Asian Agri-History*, *20*(4).
7. Rehman, A., Jingdong, L., Khatoon, R., Hussain, I., & Iqbal, M. S. (2016). Modern agricultural technology adoption its importance, role and usage for the improvement of agriculture. *Life Science Journal*, *14*(2), 70-74.

Unit:2

BRANCHES AND ALLIED SCIENCES IN AGRICULTURE

Compiled by: Dr. Muhammad Shaukat
Mr. Tauqeer Ahmed
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

INTRODUCTION : 11
OBJECTIVES : 11
LEARNING OUTCOMES: 11
2.1 Agriculture: 12
2.2 Branches of Agriculture: 12
2.2. 1 Plant Science: 12
2.2.2 Branches of Plant Science: 13
2.3 Soil and Water Sciences 14
2.3.1 Scope of Soil and Water Sciences 14
2.3.2 Core Areas of Study 15
2.3.3 Applications: 15
2.4 Agricultural Economics 16
2.4.1 Scope of Agricultural Economics 16
2.4.2 Importance of Agricultural Economics 17
2.4.3 Tools & Methods Used 17
2.5 Agricultural Engineering 17
2.5.1 Branches of Agricultural Engineering 18
2.5.2 Core Subjects in Agricultural Engineering 18
2.5.3 Career Opportunities 18
2.5.4 Emerging Technologies in Agricultural Engineering 19
2.6. Food Sciences and other post-harvest technologies: 19
2.6.1 Food Sciences 19
2.6.2 Post-Harvest Technologies 20
2.6.3 Integration of Food Science & Post-Harvest Technology 21
2.6.4 Emerging Trends 21
2.7 Self-Assessment Questions 22
2.8 References 22

INTRODUCTION :

Agriculture is a broad field that not only focuses on crop production, but also connects with many specialized branches and allied sciences. These branches, such as agronomy, horticulture, soil science, plant pathology, agricultural engineering, animal husbandry, and agricultural economics, help in understanding and solving different aspects of farming. Allied sciences like biotechnology, forestry, fisheries, and food technology further strengthen agriculture by providing modern tools and techniques.

Studying these branches and allied sciences gives a complete picture of how agriculture works as a system, combining plants, animals, soil, water, machinery, and economics. This knowledge helps in improving productivity, protecting resources, and ensuring food security for the growing population.

OBJECTIVES :

The main objectives of this unit are to:

1. Introduce students to the major branches of agriculture, such as agronomy, horticulture, soil science, plant pathology, agricultural economics, and agricultural engineering.
2. Explain the role of allied sciences like forestry, fisheries, animal husbandry, food technology, and biotechnology in strengthening agriculture.
3. Develop an understanding of how different branches and allied sciences are interconnected in improving farm production and resource management.
4. Highlight the practical applications of each branch in solving agricultural problems and ensuring food security.
5. Encourage appreciation of the multidisciplinary nature of agriculture and its contribution to economic growth and sustainable development.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. Identify and describe the major branches of agriculture, such as agronomy, horticulture, soil science, plant pathology, agricultural economics, and agricultural engineering.
2. Explain the contribution of allied sciences like animal husbandry, forestry, fisheries, food technology, and biotechnology to agricultural development.

3. Differentiate between the roles of various agricultural branches and how they complement one another.
4. Analyze the importance of integrating branches and allied sciences to solve agricultural challenges and increase productivity.
5. Apply basic knowledge of these fields to understand real-life agricultural practices and problems.
6. Appreciate the multidisciplinary nature of agriculture and its role in ensuring sustainability, food security, and economic growth.

2.1 Agriculture:

The term Agriculture is derived from two Latin words: **ager** or **agri,** meaning **soil** and **cultura,** meaning **cultivation**. Agriculture is an applied science that encompasses all aspects of crop production, including horticulture, livestock rearing, fisheries, forestry, etc.

Agriculture is defined as an art, science and business of producing crops and livestock for economic purposes.

As an art, it embraces knowledge of the way to perform the operations of the farm in a skillful manner, but does not necessarily include an understanding of the principles underlying the farm practices.

As a science, it utilizes all technologies developed on scientific principles, such as crop breeding, production techniques, crop protection, economics, etc., to maximize the yield and profit. For example, new crops and varieties developed by hybridization, Transgenic crop varieties resistant to pests and diseases, hybrids in each crop, high fertilizer-responsive varieties, water management, herbicides to control weeds, use of bio-control agents to combat pests and diseases, etc.

As the business: As long as agriculture is the way of life of the rural population, production is

ultimately bound to consumption. But agriculture as a business aims at maximum net return through the management of land, labour, water and capital, employing the knowledge of various sciences for the production of food, feed, fibre and fuel. In recent years, agriculture has been commercialized to run as a business through mechanization.

2.2 Branches of Agriculture:

2.2. 1 Plant Science:

Plant science, a major branch of agriculture, encompasses several specialized fields, including agronomy, horticulture, plant breeding, plant pathology, and soil

science. These fields focus on different aspects of plant cultivation, improvement, and management to ensure food security and sustainable agricultural practices.

2.2.2 Branches of Plant Science:

2.2.1 Agronomy – Deals with the production of various crops, which include food crops, fodder crops, fibre crops, sugar, oilseeds, etc. The aim is to have better food production and to control the diseases. In addition, agronomists work in the areas of plant genetics, plant physiology, meteorology, and soil science. Agronomy is the application of a mixture of sciences like biology, chemistry, economics, ecology, earth science, and genetics.

Today, Agronomists are concentrating on many issues,such as food production, producing healthier food, managing the impact of agriculture on the environment, and extracting energy from plants. Agronomists specialize in areas such as crop rotation, irrigation and drainage, soil classification, soil fertility, weed control, and insect/pest control.

2.2.2.2 Horticulture - Deals with the production of fruits, vegetables, flowers, ornamental plants, spices, condiments and beverages.

2.2.2.2.1 Branches of Horticulture

Horticulture is broadly divided into five main branches:

Pomology – Study and cultivation of fruits

Example: Mango, apple, banana, grapes.

Olericulture – Cultivation of vegetables

Example: Tomato, cabbage, brinjal, carrot.

Floriculture – Production and management of flowers

Example: Roses, orchids, marigolds.

Landscape Gardening – Designing and maintaining parks, gardens, and green spaces.

Post-Harvest Technology – Storage, processing, packaging, and preservation of horticultural produce.

Importance of Horticulture

Nutritional Value → Provides fruits & vegetables rich in vitamins & minerals.

Economic Value → High profit from cash crops like strawberries, orchids, and spices.

Environmental Benefits → Reduces pollution, improves greenery, and supports biodiversity.

Aesthetic Value → Beautifies surroundings with landscaping and floriculture.

Employment Opportunities → Jobs in farming, research, landscaping, greenhouse management, etc.

2.2.2.3 Plant Breeding– Plant Breeding/Genetics is defined as the art and science of changing the genetic architecture and traits of plants in order to produce desired characteristics.

This can be accomplished through many different ways, ranging from selecting plants with desirable characteristics to more complex molecular techniques.

Moreover, this technique has been practiced for thousands of years, since near the beginning of human civilization. Many individuals, such as gardeners, farmers, and professional plant breeders practicing it worldwide, which are employed by organizations such as agricultural universities, crop-specific industry associations, research centers, and various government institutions.

2.2.2.4 Plant Pathology _ Plant Pathology is the branch of agricultural science that deals with the cause of disease, the disorder in the plant, and the management of plant disease.

However, also involves the study of the interaction between the plant and pathogen, identification of the pathogen, disease cycle, economic impact, and how plantdisease will affect humans in relation to the overall environment.

Moreover, the disease-causing organisms include fungi, oomycetes, bacteria, viruses, viroids, virus-like organisms, phytoplasmas, protozoa, nematodes, and parasitic plants.

While insects, pests, mites, vertebrates, or other pests are not included because they affect plant health by consuming plant tissues.

2.2.2.5 Soil science – Soil Science is the study of soil as a natural body developed by natural forces on the surface of the earth in which plants grow. Properties of soil in relation to the use and management of soil, include soil formation, classification, and mapping of physical, chemical, biological, and fertility properties of soils.

Soil scientists are concentrating on the ways to preserve soil and arable land with a growing population, an upcoming future water crisis, increasing per capita food consumption, and degradation of land.

2.3 Soil and Water Sciences

Soil and water sciences deal with the geological generation of soil, soil and water physics and chemistry, and all other factors relevant to soil fertility.

2.3.1 Scope of Soil and Water Sciences

This field studies:

Soil properties: Texture, structure, porosity, nutrient content, and fertility.

Water resources: Distribution, availability, and quality of groundwater and surface water.

Soil-water interaction: How water moves through soil, affects plant growth, and interacts with nutrients.

Environmental sustainability: Managing pollution, salinity, erosion, and desertification.

Climate change impacts: Effects of droughts, floods, and rising temperatures on soil and water systems.

2.3.2 Core Areas of Study

A. **Soil Science**

Soil Physics → Water retention, infiltration, drainage, and aeration.

Soil Chemistry → Nutrient availability, pH, salinity, and pollutant interactions.

Soil Biology & Microbiology → Microbes, organic matter decomposition, and soil fertility.

Soil Classification & Mapping → Identifying soil types for agriculture, engineering, and conservation.

B. Water Science

Hydrology → Movement of water through the atmosphere, land, and underground.

Water Quality → Monitoring pollutants, salinity, heavy metals, and organic matter.

Irrigation & Drainage → Designing efficient water use systems for agriculture.

Groundwater & Aquifer Management → Understanding recharge, depletion, and contamination.

2.3.3 Applications:

Soil and water sciences have practical importance in:

Agriculture → Enhancing crop yields through soil fertility and irrigation management.

Environmental Protection → Controlling erosion, land degradation, and water pollution.

Water Resource Management → Sustainable use of freshwater and prevention of scarcity.

Climate Change Mitigation → Carbon sequestration in soils and efficient water use.

Engineering & Land Use Planning → Soil stability for construction, dams, and urban planning.

Emerging Research Areas

Remote sensing & GIS in soil and water mapping

Smart irrigation systems using IoT & AI

Microplastic pollution in soils and water

Biochar and organic amendments for soil health

Water desalination and treatment technologies

2.4 Agricultural Economics

Agricultural economics is a branch of agriculture that deals with the utilization of scarce resources. It aims at maximizing output while minimizing costs. The field of agricultural economics includes agricultural finance, policy, marketing, farm and agribusiness management, rural sociology, and agricultural law.

2.4.1 Scope of Agricultural Economics

The field covers a wide range of topics:

a) Farm Management

Analyzing costs, revenues, and profitability.

Deciding on crop mix, irrigation, and technology adoption.

Optimizing the use of resources like labor, machinery, and fertilizers.

b) Agricultural Production Economics

Studying the relationship between inputs (land, labor, fertilizers) and outputs (crops, livestock).

Using production functions to determine efficiency.

c) Agricultural Marketing

Understanding how agricultural products reach consumers.

Studying demand, supply, price formation, and market structures.

Role of cooperatives, storage, and transportation.

d) Agricultural Finance

Sources of farm credit (banks, cooperatives, microfinance).

Managing loans, subsidies, and risk in farming.

e) Agricultural Policy

Analyzing the impact of government policies on farming.

Includes price supports, subsidies, trade policies, and rural development programs.

f) International Trade & Food Security

Export and import of agricultural products.

Global food security and self-sufficiency.

g) Natural Resource & Environmental Economics

Sustainable use of land, water, and forests.

Impact of climate change on agriculture.

2.4.2 Importance of Agricultural Economics

Agricultural economics plays a vital role in both developed and developing countries:

For Farmers: Helps them make decisions about what, when, and how to produce for maximum profit.

For Policymakers: Provides insights for designing effective agricultural policies.

For Consumers: Ensures a stable food supply and fair pricing.

For the Economy: Agriculture is the backbone of many economies, especially in developing countries.

2.4.3 Tools & Methods Used

Agricultural economists use several techniques, such as:

Cost-benefit analysis → To evaluate farm decisions.

Econometrics & statistics → To analyze production, pricing, and demand.

Linear programming → To optimize farm resource allocation.

Risk analysis → To manage uncertainties like droughts and price fluctuations.

2.5 Agricultural Engineering

Agriculture engineering is a branch of agriculture that deals with the use and maintenance of farm tools, machinery and structures. Agricultural engineering includes selective areas of mechanical, electrical, environmental, and civil engineering, construction technology, hydraulics, and soil mechanics that are related to agricultural and farm problems. Four primary branches have developed within agricultural engineering, based on the problems encountered: farm power and machinery engineering, farm structures engineering, soil and water control engineering, and electric power and processing engineering.

2.5.1 Branches of Agricultural Engineering

There are several specialized areas within agricultural engineering:

a) Farm Machinery & Power Engineering

Design, manufacture, and maintenance of tractors, harvesters, seeders, and other farm equipment.

Automation and robotics in agriculture.

b) Soil & Water Conservation Engineering

Irrigation systems, drainage, and watershed management.

Efficient use of water resources and prevention of soil erosion.

c) Agricultural Process & Food Engineering

Post-harvest technology, food storage, processing, and packaging.

Development of machinery for milling, drying, and refrigeration.

d) Renewable Energy & Bioenergy

Solar-powered irrigation, wind energy, biomass, and biofuel production.

Sustainable energy solutions for rural farming communities.

e) Precision & Smart Farming

Use of AI, IoT, drones, GPS, and sensors for efficient farming.

Data-driven decision-making for better yield and resource management.

2.5.2 Core Subjects in Agricultural Engineering

If you're studying Agricultural Engineering (B.Tech, B.E., or similar), here are the major subjects:

Engineering Basics: Mechanics, Thermodynamics, Fluid Mechanics

Agricultural Basics: Crop Production, Soil Science, Horticulture

Farm Machinery: Tractor Systems, Equipment Design, Power Units

Irrigation & Drainage Engineering

Renewable Energy & Environmental Engineering

Post-Harvest Technology & Food Processing

GIS, Remote Sensing & Smart Farming

Automation & AI Applications in Agriculture

2.5.3 Career Opportunities

Agricultural Engineering offers diverse career options in both government and private sectors:

a) Government Jobs

Agricultural departments

Irrigation & water resource authorities

Food Corporation of India (FCI)

Indian Council of Agricultural Research (ICAR)

NABARD & state agriculture boards

b) Private Sector

Food processing companies

Agro-machinery manufacturing firms

Seed, fertilizer, and pesticide industries

Agri-tech startups (drones, IoT, AI solutions)

c) Research & Higher Studies

M.Tech / M.E. in Agricultural Engineering

Research opportunities in climate-smart agriculture, robotics, AI, and bioenergy

2.5.4 Emerging Technologies in Agricultural Engineering

Agricultural engineering is becoming high-tech. Here are some modern trends:

Smart Farming: Use of IoT devices and AI for crop monitoring.

Drones in Agriculture: For spraying, mapping, and monitoring.

Hydroponics & Vertical Farming: Soil-less farming for urban agriculture.

Robotics & Automation: Self-driving tractors, robotic weed removers.

Climate-Smart Agriculture: Sustainable practices to combat climate change.

Biotechnology Integration: High-yield and drought-resistant crop development

2.6. Food Sciences and other post-harvest technologies:

A group of sciences and technologies underlie the processing, storage, distribution, and marketing of agricultural commodities and by-products. Modern post-harvest technology helps provide inexpensive and various food supplies for consumers, meets the demands of a variety of industrial users, and even creates replacements for fossil fuels.

2.6.1 Food Sciences

Food science is the multidisciplinary study of the physical, biological, and chemical makeup of food and the concepts underlying food processing and preservation. It combines principles from chemistry, microbiology, nutrition, and engineering to improve food quality, safety, and shelf life.

Major Areas of Food Science

Food Chemistry – Studies composition, properties, and chemical changes in food (e.g., browning in fruits, lipid oxidation).

Food Microbiology – Focuses on microorganisms in food, including spoilage organisms and foodborne pathogens.

Food Engineering – Involves designing processing systems, packaging, and storage solutions.

Food Processing & Preservation – Techniques like drying, freezing, canning, and irradiation to extend shelf life.

Food Safety & Quality Assurance – Ensures compliance with standards like HACCP, ISO, and FSSAI.

Nutrition & Functional Foods – Development of foods with added health benefits, like fortified cereals or probiotics.

2.6.2 Post-Harvest Technologies

Post-harvest technology deals specifically with all the steps after crop harvesting to maintain quality, reduce losses, and enhance shelf life until the product reaches consumers.

Importance of Post-Harvest Technologies

Reduces post-harvest losses (which can be 20–40% in developing countries).

Maintains nutritional value, taste, and appearance.

Improves marketability and export quality.

Enhances food security by reducing wastage.

Key Post-Harvest Operations

A. Primary Handling

Sorting and grading to remove damaged or diseased produce.

Cleaning and washing to reduce microbial load.

Pre-cooling to quickly lower the field heat.

B. Storage Technologies

Cold storage & refrigeration – Extends the shelf life of fruits, vegetables, dairy, and meat.

Controlled Atmosphere (CA) storage – Adjusting oxygen, carbon dioxide, and humidity levels.

Modified Atmosphere Packaging (MAP) – Special packaging to slow down spoilage.

C. Processing Technologies

Minimal processing: Fresh-cut vegetables, ready-to-eat salads.

Thermal processing: Canning, pasteurization, and sterilization.

Non-thermal techniques: High-pressure processing, pulsed electric fields, and UV treatments.

D. Packaging Technologies

Vacuum packaging to inhibit microbial growth.

Active packaging that absorbs oxygen or releases preservatives.

Edible coatings made from natural polymers to slow ripening.

E. Transportation & Distribution

Use of temperature-controlled supply chains ("cold chains").

Packaging designs to minimize physical damage during transit.

2.6.3 Integration of Food Science & Post-Harvest Technology

Food science and post-harvest technology work hand in hand:

Aspect	**Food Science**	**Post-Harvest Technology**
Focus	Quality, nutrition, safety, processing	Preservation, storage, transport
Approach	Laboratory-based, product-oriented	Field-to-market oriented
Goal	Improve consumer health & product development	Reduce losses, maintain quality
Example	Developing low-fat milk powder	Extending milk shelf life via the cold chain

2.6.4 Emerging Trends

Smart Packaging: Sensors that monitor freshness and spoilage.

Nanotechnology: For better food preservation and pathogen detection.

AI & IoT in Post-Harvest Handling: Smart warehouses, supply chain monitoring.

Sustainable Food Processing: Minimizing waste and energy usage.

Biotechnology Applications: Enzyme-based ripening control, edible vaccines, bio-preservatives.

2.7 Self-Assessment Questions

Fill the blanks

1. The term Agriculture is derived from _____ word.
2. Cultura meaning_____.
3. _____is an applied science which encompasses all aspects of crop production, including horticulture, livestock rearing, fisheries, forestry, etc.
4. _____ branch of agriculture deals with the production of various crops which includes food crops, fodder crops, fibre crops, sugar, oilseeds
5. _____is the branch of agricultural science which deals with the cause of disease, the disorder in the plant, and the management of plant disease.

Answers

1) Latin 2) cultivation 3) Agriculture 4) Agronomy 5) Plant Pathology

2.8 References

1. Gohari, A. A. (2012). International Journal of Farming and Allied Sciences.
2. Hepper, L. Research and Reviews: Journal of Agriculture and Allied Sciences.
3. Paul, P., & Aithal, P. S. (2020). Environment and Studies related to Environmental Sciences: The Overview of Allied Areas. *Educational Quest: An Int. J. of Education and Applied Social Science*, *11*(1), 01-05.
4. PLANT, C. D. I. I. (2016). Indian Journal of Agriculture and Allied Sciences. *Convergence*, *2*(1).
5. Rathinasabapathy, G., & Veeranjaneyulu, K. (2022). Open Access Journals in Agriculture and Allied Sciences: A Study based on Directory of Open Access Journals (DOAJ). *Library Philosophy and Practice*, 1-14.
6. Vignesh, K., Vengadeshkumar, L., Rajamohan, K., & Sanjaygandhi, S. (2023). ARCHIVES OF AGRICULTURE AND ALLIED SCIENCES.

Unit:3

SALIENT FEATURES AND PROBLEMS OF PAKISTAN'S AGRICULTURE

Compiled by: Dr. Muhammad Shaukat
Mr. Tauqeer Ahmed
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

Introduction: 26
Objectives : 26
Learning outcomes: 26
3.1. Role of Agriculture in Pakistan's Development 27
3.2. Major Crops of Pakistan 27
3.3. Agriculture sub-sector: Livestock 28
3.3.1 Key Aspects of Pakistan's Livestock Sector: 28
3.4 Agriculture sub-sector: Forest 31
3.4.1. Importance of Forestry in Pakistan 31
3.4.2. Forest Area and Types of Forests 32
3.4.3 Forest Types in Pakistan: 32
3.4.4. Key Challenges Facing Forestry in Pakistan 32
3.4.5. Forest Resources in Pakistan 33
3.4.6. Government and Policy Framework 33
3.4.7. Opportunities for Development 33
3.4.8. Key Forest Regions in Pakistan 34
3.5. Agriculture Sub sector: Fisheries 34
3.5.1. Contribution to the Economy 34
3.5.2. Geography of Fisheries in Pakistan 35
3.5.3. Fish Species 35
3.5.4. Challenges Facing the Fisheries Sector 35
3.5.5. Fisheries Management and Policies 36
3.5.6. Opportunities for Growth 36
3.5.7. Key Fisheries Organizations in Pakistan 36
3.5.8. Key Export Markets 37
3.6 Agriculture Sub sector: Rangeland 37
3.6.1. Geographical Distribution: 37

3.6.2. Area and Size: 37
3.6.3. Climate: 37
3.6.4 Types of Rangelands 37
3.6.5 Importance of Rangelands 38
3.6.6 Challenges Facing Pakistan's Rangelands 38
3.6.7 Management and Conservation Efforts 39
3.7 Problems of Pakistan Agriculture 40
3.7.1. Water Scarcity and Mismanagement 40
3.7.2. Climate Change and Environmental Challenges 40
3.7.3. Inadequate Infrastructure 41
3.7.4. Low Productivity and Traditional Farming Practices 41
3.7.5. Over-reliance on Traditional Crops 41
3.7.6. Pest and Disease Management 41
3.7.7 Financial Constraints 41
3.7.8. Land Tenure Issues 42
3.7.9. Market Access and Price Fluctuations 42
3.7.10. Limited Agricultural Policy Support 42
3.7.11. Labor Shortages 42
3.7.12. Poor Health and Nutrition 42
3.7.13 Ways to Address These Issues: 43
3.8 Self-Assessment Questions 43
3.9 References 44

INTRODUCTION:

The agricultural sector of Pakistan has some unique and important features, such as fertile plains, an extensive canal irrigation system, diverse climatic conditions, and the production of major crops like wheat, rice, cotton, and sugarcane. These features make agriculture a vital contributor to national development.

However, Pakistan's agriculture also faces many serious problems. Issues like water scarcity, soil degradation, small landholdings, low productivity, outdated farming practices, lack of modern technology, and the effects of climate change hinder its progress. Understanding these features and challenges is essential for planning improvements and ensuring sustainable agriculture in the country.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the key features of Pakistan's agriculture, including climate, soil, irrigation system, and major crops.
2. Highlight the role of agriculture in Pakistan's economy, food security, and rural development.
3. Identify the major problems and challenges faced by the agricultural sector, such as water shortage, low productivity, and climate change.
4. Develop an understanding of the causes and impacts of these problems on farmers and the national economy.
5. Encourage students to think about possible solutions and modern practices for improving agriculture in Pakistan.
6. Create awareness about the need for sustainable agricultural development to meet future demands.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. Describe the salient features of Pakistan's agriculture, including climate, soils, irrigation systems, and major crops.
2. Explain the significance of agriculture in the country's economy, employment, and food security.
3. Identify and discuss the major problems faced by the agricultural sector, such as water scarcity, small landholdings, low yields, and climate-related challenges.
4. Analyze the causes and impacts of these problems on farmers, rural communities, and national development.

5. Suggest possible solutions and modern practices to overcome the challenges and improve agricultural productivity.

3.1. Role of Agriculture in Pakistan's Development

3.1.2 Major Contributor to GDP

- Agriculture contributes around 23.54% to Pakistan's GDP.
- Employs over 42.3% of the labor force (as of recent stats).

2. **Main Source of Livelihood**

- The majority of the rural population depends on agriculture for income and employment.

3. **Diverse Agro-Climatic Zones**

- From the fertile plains of Punjab to the arid regions of Balochistan, allowing for diverse crop cultivation (wheat, rice, cotton, sugarcane, fruits).

4. **Cropping Seasons**

- Kharif (summer): rice, cotton, sugarcane, maize.
- Rabi (winter): wheat, barley, mustard, gram.

5. **Irrigation-Dependent System**

- The world's largest contiguous canal irrigation system from the Indus River.
- Over 80% of cultivated land is irrigated.

6. **Dominance of Small Land Holdings**

- A large number of farms are small (less than 5 hectares), leading to subsistence farming.

7. **Livestock Integration**

- Livestock contributes around 60% of agricultural value.
- Provides dairy, meat, hides, and draught power.

8. **Major Exporter of Agricultural Goods**

- Exports include rice, cotton, fruits (mangoes, kinnow), vegetables, and textiles made from cotton.

3.2. Major Crops of Pakistan

1. **Wheat**

- Season: Rabi (Winter)
- Importance: Staple food of Pakistan; main food crop.
- Major Growing Areas: Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan.

2. **Rice**

- Season: Kharif (Summer)
- Importance: Second most important food crop; a key export.
- Major Varieties: Basmati, IRRI-6, IRRI-9.
- Major Growing Areas: Punjab, Sindh.

3. **Cotton**

- Season: Kharif
- Importance: Main cash crop; crucial for the textile industry.
- Major Growing Areas: Punjab, Sindh.

4. **Sugarcane**

- Season: Kharif
- Importance: Source of sugar and related industries like ethanol.
- Major Growing Areas: Punjab, Sindh, Khyber Pakhtunkhwa.

5. **Maize (Corn)**

- Season: Both Rabi and Kharif (primarily Kharif)
- Importance: Used as food, fodder, and for industrial purposes.
- Major Growing Areas: Punjab, Khyber Pakhtunkhwa.

3.3. Agriculture sub-sector: Livestock

The livestock sector is a vital part of Pakistan's agriculture and economy, contributing significantly to rural livelihoods and the national economy. It plays a major role in providing food, employment, and raw materials for various industries.

3.3.1 Key Aspects of Pakistan's Livestock Sector:

3.3.1.1. Economic Contribution:

- Contribution to GDP: The livestock sector contributes around 14.97% to Pakistan's GDP and about 63% of the agricultural GDP.
- Employment: The sector employs over 8-10 million people, especially in rural areas, where it is a major source of income.

3.3.1.2. Livestock Products:

- Meat: Pakistan is one of the leading producers of beef, mutton, and chicken. Cattle, buffaloes, sheep, and goats are commonly raised for meat production.
- Dairy: Dairy production is a significant part of the livestock sector. Pakistan has the largest buffalo population in the world, and it also has a large number of cows for milk production. Dairy farming is a major source of income for farmers, and dairy products such as milk, yogurt, and butter are widely consumed.
- Wool and Hides: Sheep are raised for wool and hides, which are used for leather production. Pakistan's leather industry relies heavily on livestock for its raw materials.
- Manure and Fertilizers: Animal manure is an important resource for organic farming, and it also provides fuel in rural areas.

3.3.1.3. Livestock Population:

- Cattle: Around 59.7 million head of cattle are found across the country.
- Buffaloes: Pakistan has one of the world's largest buffalo populations, with over 47.7 million buffaloes.
- Sheep: There are approximately 33.1million sheep in Pakistan.
- Goats: Around 89.4 million goats are raised in the country, mostly for meat production.
- Poultry: Pakistan's poultry industry has grown rapidly over the years and is a major contributor to meat production, with millions of chickens raised for both eggs and meat.

3.3.1.4. Challenges Faced by the Livestock Sector:

- Disease Outbreaks: Livestock diseases like foot-and-mouth disease, lumpy skin disease, and avian influenza frequently affect animal health and production.
- Inadequate Veterinary Services: Despite progress, veterinary infrastructure in rural areas remains underdeveloped, leading to delays in disease control and prevention.
- Climate Change: Extreme weather events, droughts, and rising temperatures have negative impacts on grazing lands, water sources, and the overall health of livestock.
- Poor Animal Genetics: While there are some high-yielding breeds, Pakistan's livestock sector often suffers from low productivity due to poor animal genetics, lack of modern breeding practices, and insufficient research and development in animal husbandry.

- Feed and Nutrition Issues: A lack of proper animal feed and nutritional balance leads to reduced milk and meat production. Many farmers depend on traditional, low-quality feed.
- Land Use Issues: Overgrazing and lack of proper pasture management result in the depletion of grazing lands.
- Limited Access to Markets and Finance: Farmers in the livestock sector often face difficulties in accessing modern markets, credit facilities, and fair prices for their products.

3.3.1.5. Government Policies and Initiatives:

- Livestock Development Projects: The government has launched various programs to enhance productivity, improve breeding techniques, and promote the use of modern veterinary services.
- Veterinary Training and Awareness Campaigns: Efforts have been made to increase awareness among farmers about livestock management, disease prevention, and vaccination programs.
- Financial Support for Small Farmers: The government and various NGOs have introduced schemes to help small-scale farmers access credit, modern equipment, and technology to improve their livestock production systems.
- Export Promotion: Pakistan has been making efforts to increase livestock exports, especially beef, mutton, and dairy products. This includes improving meat processing facilities and meeting international health and safety standards.

3.3.1.6. Regional Distribution:

- Punjab: The largest livestock population, especially of buffaloes, cattle, and poultry, is found in Punjab, which is also the country's major milk-producing region.
- Sindh: Sindh has a significant number of cattle, goats, and sheep. The livestock sector here also supports the meat industry, with Karachi being a key hub for livestock trading.
- Khyber Pakhtunkhwa (KPK): The province is known for sheep and goat farming, especially in mountainous areas.
- Balochistan: This province is more known for sheep, goats, and camel farming. The sector is mainly rural and less commercialized than in other provinces.

3.3.1.7. Opportunities for Growth:

- Export Potential: Pakistan has significant potential to boost its livestock product exports, especially to Middle Eastern and Asian markets.

- Value-added Products: There is an opportunity to add value to livestock products through processing (e.g., cheese, ghee, yogurt, and leather goods).
- Improved Veterinary Services: Expanding veterinary care, including better access to vaccines and disease management, could greatly enhance productivity.
- Sustainable Farming Practices: Shifting to more sustainable and efficient farming practices can help address the environmental challenges and improve long-term productivity.
- Genetic Improvement: Focusing on improving the genetic quality of animals through modern breeding practices could lead to increased productivity.

3.3.1.8. Livestock and Rural Development:

- Livestock farming has a strong link to rural development in Pakistan. It supports rural economies through income generation, food security, and employment, particularly for women, who are often involved in milk production and animal care.

3.3.1.9. Recent Trends:

- The rise of modern dairy farms and commercial poultry farms is gradually transforming the landscape of Pakistan's livestock sector. Larger, more industrialized operations are emerging, especially in Punjab.
- There’s increasing interest in organic livestock production due to growing global demand for organic products.

3.4 Agriculture sub-sector: Forest

3.4.1. Importance of Forestry in Pakistan

- Economic Contribution: Forestry contributes to the national economy by providing raw materials for industries such as timber, paper, and furniture. It also contributes to the livelihoods of rural communities.
- Livelihood Support: About 2 million people in Pakistan depend on forestry for their livelihood. This includes people engaged in forest-based activities such as timber cutting, collection of non-timber forest products (NTFPs), and working in the wood-based industry.
- Environmental Services: Forests play a vital role in preventing soil erosion, regulating water cycles, maintaining biodiversity, and supporting the carbon sink. Pakistan's forests also contribute to mitigating climate change by absorbing carbon dioxide.

3.4.2. Forest Area and Types of Forests

According to the FAO (Food and Agriculture Organization), Pakistan's forest cover is relatively small compared to its total land area. The country's forest area is around 5% of its total land area, which is quite low compared to other countries in the region.

3.4.3 Forest Types in Pakistan:

- Tropical and Subtropical Forests: Found in areas like Sindh, Punjab, and Balochistan.
- Temperate Forests: Found in the mountainous regions of Khyber Pakhtunkhwa (KP), Azad Jammu and Kashmir (AJK), and Gilgit-Baltistan (GB).
- Montane and Alpine Forests: Found at higher elevations, particularly in the northern mountainous regions.

The major forest types in Pakistan include coniferous, broadleaf, mixed, and scrub forests. These forests consist of species such as deodar, pine, oak, and other broad-leafed trees.

3.4.4. Key Challenges Facing Forestry in Pakistan

- Deforestation and Forest Degradation: Over the years, Pakistan has experienced substantial deforestation due to illegal logging, urbanization, and the expansion of agricultural land. Deforestation has led to soil erosion, floods, and the loss of biodiversity.
- Illegal Logging and Over-exploitation: The illegal cutting of trees for timber, firewood, and other forest products is a major challenge. A lack of effective monitoring and enforcement makes it difficult to combat illegal practices.
- Climate Change: Pakistan's forests are also vulnerable to the impacts of climate change, which include increasing temperatures, changing rainfall patterns, and increased frequency of forest fires. These impacts can affect forest regeneration and the survival of many species.
- Overgrazing and Land Use Change: Livestock grazing in forest areas and the conversion of forest land to agricultural use are significant contributors to forest degradation.
- Inadequate Forest Management: Forest management practices are often outdated and insufficient, which impacts the long-term sustainability of forests. There is also a lack of community involvement in forest management decisions.

3.4.5. Forest Resources in Pakistan

- Timber: Timber is a major resource obtained from forests, primarily used in construction, furniture making, and paper production. Key timber species include deodar (Cedrus deodara), pine, and fir.
- Non-Timber Forest Products (NTFPs): Forests also provide a wide range of NTFPs such as medicinal plants, edible fruits, nuts, and herbs, which are an important source of income for local communities.
- Fuelwood: A significant portion of the rural population in Pakistan relies on fuelwood for cooking and heating. Fuelwood collection contributes to deforestation, especially in areas with limited access to alternative energy sources.

3.4.6. Government and Policy Framework

The Government of Pakistan has undertaken several initiatives to address the challenges facing the forestry sector. Some key policies and programs include:

- National Forest Policy (2015): The National Forest Policy aims to address deforestation, improve forest management, and promote the sustainable use of forest resources. It emphasizes community-based forestry and the involvement of local populations in forest conservation efforts.
- Ten Billion Tree Tsunami Project: Launched in 2018 by the Government of Khyber Pakhtunkhwa (KP) and later adopted nationwide, the project focuses on large-scale reforestation efforts to restore degraded forest areas. The goal is to plant 10 billion trees across the country.
- Forest Acts and Laws: Pakistan has several laws and regulations related to forest protection, such as the Forest Act of 1927, but enforcement remains a challenge.
- Community Forest Management: The involvement of local communities in forest management is increasingly being recognized as an effective way to protect and restore forests. Community-based organizations (CBOs) and forest user groups are encouraged to participate in the conservation and sustainable management of forests.

3.4.7. Opportunities for Development

- Reforestation and Afforestation: The government and various non-governmental organizations (NGOs) are focusing on reforestation and afforestation efforts. These initiatives aim to restore degraded forest land and expand forest cover.

- Sustainable Forest Management: Improving forest management practices through scientific techniques, monitoring, and enforcement of regulations can help ensure the long-term sustainability of forests.
- Eco-tourism: The biodiversity and scenic beauty of forests in Pakistan can be harnessed for eco-tourism. This can provide both economic benefits and help raise awareness about the importance of forest conservation.
- Promotion of Alternative Energy Sources: Reducing the dependence on fuelwood by promoting alternative energy sources such as biogas, solar energy, and improved cookstoves can help reduce pressure on forests.

3.4.8. Key Forest Regions in Pakistan

- Khyber Pakhtunkhwa (KP): The province is home to a number of temperate forests, particularly in the districts of Swat, Chitral, and Dir. KP has significant forest resources, especially in the form of coniferous forests.
- Azad Jammu and Kashmir (AJK): AJK has a diverse range of forests, including tropical and temperate forests. This region is known for its rich biodiversity and scenic forest landscapes.
- Gilgit-Baltistan (GB): The northern mountainous region is rich in forests, including pine, spruce, and fir forests. GB has significant potential for reforestation and afforestation.
- Balochistan: The forest cover in Balochistan is sparse, but it has dry and scrub forests in areas like Zhob, Khuzdar, and Sibi.
- Sindh and Punjab: These regions have tropical forests, but the forest cover is limited. Efforts are being made to restore and increase forest cover, especially through the Sindh Forest Policy.

3.5. Agriculture Sub sector: Fisheries

Fisheries is a significant sub-sector of Pakistan's agriculture industry. It plays an important role in the country's economy by providing food, employment, and contributing to exports. Here's a detailed breakdown of the fisheries sector in Pakistan:

3.5.1. Contribution to the Economy

- GDP Contribution: The fisheries sector contributes around 1-2% to Pakistan's Gross Domestic Product (GDP). However, it has a much larger impact on rural and coastal communities, especially in provinces like Sindh and Balochistan.
- Employment: The sector provides direct and indirect employment to millions of people. Fishermen, fish farmers, processors, exporters, and

those involved in related industries like cold storage and transportation benefit from the sector.

- Exports: Pakistan exports a variety of fish and seafood products, with China, the Middle East, and Europe being major markets. Fish exports contribute significantly to Pakistan's foreign exchange earnings.

3.5.2. Geography of Fisheries in Pakistan

- Marine Fisheries: The coastal areas of Pakistan, especially along the Arabian Sea in the provinces of Sindh and Balochistan, are home to a rich marine ecosystem. Key fishing ports include Karachi, Pasni, and Gwadar.
- Marine Resources: Pakistan has a coastline of over 1,000 kilometers, rich in marine life. Common species include shrimp, prawns, mackerel, tuna, sardines, and hilsa.
- Inland Fisheries: Inland fishing takes place in rivers, lakes, and reservoirs across the country. Major inland fisheries are found in the Indus River, Mangla Dam, Chashma Barrage, and the Keenjhar Lake.
- Aquaculture: There has been significant development in freshwater aquaculture, with fish farming systems used for species such as carps, catfish, and tilapia.

3.5.3. Fish Species

Marine Fish Species:

- Shrimp: Pakistan is known for its large shrimp catches, especially the Penaeid shrimp.
- Mackerel: A popular fish in Pakistan's coastal waters.
- Tuna: Both yellowfin and bigeye tuna are caught in Pakistan’s deep-sea waters.

Inland Fish Species:

- Carps: Major species farmed include Common Carp, Rohu, and Mrigal.
- Catfish: Indian Catfish (Magur) is commonly found in inland waters.
- Tilapia: Though introduced in the last few decades, tilapia farming has gained popularity in freshwater aquaculture.

3.5.4. Challenges Facing the Fisheries Sector

- Overfishing: Unsustainable fishing practices and over-exploitation of fish stocks are significant challenges. The decline in marine fish populations is a concern.
- Illegal Fishing: Illegal, unreported, and unregulated (IUU) fishing is a common problem, especially in international waters.

- Climate Change: Changing ocean temperatures and weather patterns affect fish migration and breeding cycles, threatening the livelihoods of fishermen.
- Pollution: Water pollution from industries, agricultural runoff, and oil spills adversely affects marine life and fish quality.
- Lack of Modern Technology: Limited use of modern fishing techniques, such as sonar and GPS systems, reduces fishing efficiency and catches.

3.5.5. Fisheries Management and Policies

- Government Initiatives: The government has implemented policies and schemes to improve fisheries, including subsidies for fish farms, fishing gear, and cold storage.
- Fisheries Development Departments: Provincial fisheries departments, like the Sindh Fisheries Department and Balochistan Fisheries Department, are responsible for regulating and promoting the sector.
- Research and Development: There are several organizations focused on R&D in fisheries, such as the Fisheries Research and Training Institute (FRTI) and the Marine Fisheries Department (MFD).

3.5.6. Opportunities for Growth

- Aquaculture Development: There is potential for expanding fish farming, especially in the freshwater aquaculture sector, with species like tilapia and catfish.
- Value Addition: There is room for the development of more value-added products such as fish fillets, frozen seafood, and canned products. This would not only boost local consumption but also increase export potential.
- Global Demand: With rising global demand for seafood, Pakistan has the potential to increase its market share in international markets, especially in the Middle East and Asia.
- Tourism: Fishing tourism can be developed, particularly in the coastal areas, offering sustainable livelihoods and promoting eco-tourism.

3.5.7. Key Fisheries Organizations in Pakistan

- Marine Fisheries Department (MFD): Focuses on the regulation and management of marine fish resources.
- Pakistan Fisheries Development Corporation (PFDC): A state-owned enterprise aimed at promoting the fisheries sector through modernization and development of the industry.
- Fish Processing Plants: There are several fish processing plants, especially in Karachi, that process fish for domestic consumption and export.

3.5.8. Key Export Markets

- China: The largest importer of Pakistan's seafood products.
- Middle East: Countries like the UAE, Saudi Arabia, and Qatar are major destinations for Pakistan’s seafood exports.
- European Union: The EU is a significant market for higher-value fish products, especially processed and frozen fish.

3.6 Agriculture Sub sector: Rangeland

Key Features of Pakistan's Rangelands

3.6.1. Geographical Distribution:

- Northern and Western Regions: The rangelands in Pakistan are found in the northern and western parts, especially in provinces like Balochistan, Khyber Pakhtunkhwa, and parts of Sindh. These regions have a semi-arid to arid climate, with a significant portion of the land being natural pasture.
- Indus Plains: Some rangelands are also found in the Indus Plains, particularly in floodplain areas where natural grasses grow.

3.6.2. Area and Size:

- Rangelands in Pakistan are estimated to cover around 40-50% of the total land area, which is approximately 700,000 to 800,000 square kilometers.
- These lands include deserts, mountains, and foothill areas. A large portion of rangelands is located in Balochistan, which has vast desert and semi-desert areas.

3.6.3. Climate:

- Rangelands are often found in arid and semi-arid regions, where the climate is hot and dry, with minimal rainfall.
- Temperature extremes are common, and water availability is often a limiting factor for vegetation growth.

3.6.4 Types of Rangelands

1. Arid and Semi-Arid Rangelands:

- Balochistan, Sindh, and Khyber Pakhtunkhwa have significant areas of rangelands that are often low in fertility, supporting drought-resistant vegetation like shrubs and grasses.

2. Mountainous Rangelands:

- The Himalayan and Hindu Kush mountain ranges also have rangelands that are mainly used for seasonal grazing by livestock. These areas can be more productive due to relatively higher precipitation.

3. Floodplain Rangelands:

- Punjab and parts of Sindh have rangelands located in river floodplains, where flooding provides periodic rejuvenation of grasses.

3.6.5 Importance of Rangelands

1.Livestock Grazing:

- Rangelands are crucial for grazing livestock, which supports the livelihoods of millions of rural families. Livestock production is central to the agricultural economy, especially in terms of milk, meat, and wool production.

2.Biodiversity:

- Rangelands contribute to Pakistan's biodiversity. Despite the harsh conditions, these areas support a variety of wildlife, including wild goats, sheep, and birds.

3. Carbon Sequestration:

- Rangelands also act as carbon sinks, helping to mitigate the effects of climate change by absorbing carbon dioxide.

4. Soil Conservation:

- Proper management of rangelands prevents soil erosion and land degradation, particularly in hilly and mountainous areas where deforestation and overgrazing can lead to severe erosion.

5.Cultural and Economic Significance:

- Many pastoral communities, including the Kuchi tribes, depend heavily on rangelands for their traditional grazing systems. Their nomadic way of life is tied to these lands.

3.6.6 Challenges Facing Pakistan's Rangelands

1.Overgrazing:

- A major problem for Pakistan's rangelands is overgrazing, which leads to land degradation, desertification, and the loss of productive pasture. The increasing number of livestock and lack of sustainable management practices exacerbate this issue.

1. Deforestation:

- Deforestation, particularly in the hilly regions of Khyber Pakhtunkhwa and Balochistan, impacts rangeland productivity. The removal of vegetation for firewood and agriculture increases the risk of soil erosion.

3. Water Scarcity:

- Many rangelands, particularly in arid regions, face water shortages, which hinder the growth of vegetation and reduce the grazing capacity.

4.Climate Change:

- Climate change is affecting rangeland productivity by causing more frequent droughts and erratic weather patterns. This can lead to reduced vegetation cover and loss of forage resources.

5. Land Degradation:

- Desertification and land degradation due to improper land use, including overgrazing and deforestation, are common problems. In some areas, salinity has become a significant issue.

6.Conflict Over Land Use:

- There is often competition for land resources between farmers, pastoralists, and other land users, which can result in conflicts and mismanagement of rangelands.

3.6.7 Management and Conservation Efforts

To combat the challenges facing rangelands, various steps can be taken:

1.Range Management Programs:

- Implementing rotational grazing and other sustainable grazing practices can help preserve vegetation and prevent overgrazing.

2.Reforestation and Afforestation:

- Planting trees and shrubs in degraded areas can help restore soil fertility and prevent erosion.

3.Water Management:

- Improving water availability and storage systems, such as water ponds and wells, can help support rangeland productivity.

4. Community Involvement:

- Involving local communities in rangeland management and conservation programs is essential for long-term sustainability.

5. Government and Policy Support:

- The government can play a key role in creating policies to promote sustainable rangeland management and provide financial support for conservation projects.

6. Research and Education:

- Expanding research on rangeland ecosystems and training farmers and pastoralists on better land management practices are crucial steps in improving productivity and sustainability.

3.7 Problems of Pakistan Agriculture

Pakistan's agriculture sector is a cornerstone of its economy, providing livelihoods for a significant portion of the population, particularly in rural areas. However, it faces several challenges that hinder its full potential. Here are the key problems in Pakistan's agriculture:

3.7.1. Water Scarcity and Mismanagement

- Water Shortages: Pakistan is facing a severe water crisis, with its water supply per capita steadily decreasing. The country relies heavily on the Indus River system for irrigation, but with decreasing water availability, especially in the southern and western regions, crop yields are adversely affected.
- Inefficient Irrigation Systems: A large portion of the irrigation infrastructure is outdated. The canal-based system is inefficient, leading to water wastage and inadequate irrigation of fields.
- Groundwater Depletion: Over-extraction of groundwater for irrigation is leading to the depletion of water tables, making water less accessible in many rural areas.

3.7.2. Climate Change and Environmental Challenges

- Erratic Weather Patterns: Climate change has led to unpredictable weather patterns, including extreme heat, droughts, and flooding, all of which damage crops. Such events disrupt the growing season, making it hard to predict yields.
- Soil Degradation: Overuse of chemicals, lack of proper crop rotation, and unsustainable farming practices have contributed to soil erosion, degradation, and reduced fertility, further diminishing crop productivity.

3.7.3. Inadequate Infrastructure

- Poor Rural Infrastructure: Roads, storage facilities, and market access in rural areas are underdeveloped. This limits the farmers' ability to sell their produce efficiently, leading to post-harvest losses.
- Lack of Cold Storage: Insufficient cold storage and processing facilities result in spoilage, especially for perishable goods like fruits and vegetables. As a result, farmers often lose out on potential income.

3.7.4. Low Productivity and Traditional Farming Practices

- Small-Scale Farms: The majority of farmers are smallholders with limited access to modern machinery, technology, and knowledge. This results in low productivity and outdated farming practices.
- Limited Use of Technology: Despite advances in farming technologies, many farmers still rely on traditional, manual techniques, which limit their ability to increase efficiency and yields.
- Lack of Research and Extension Services: There’s a gap in providing farmers with the latest agricultural research, modern techniques, and best practices. Extension services, which are crucial for transferring knowledge to farmers, are insufficient.

3.7.5. Over-reliance on Traditional Crops

- Monoculture Farming: Farmers often focus on a few staple crops like wheat, rice, and sugarcane, which makes the agricultural economy vulnerable to market fluctuations and climate-related disruptions.
- Underutilized Potential Crops: Pakistan has not fully tapped into the potential of high-value crops like fruits, vegetables, and pulses, which could diversify income streams and improve food security.

3.7.6. Pest and Disease Management

- Pest Infestations: Pakistan's agriculture is frequently impacted by pests and diseases, particularly in the case of cotton, rice, and wheat. These outbreaks can cause significant yield losses.
- Chemical Dependency: While pesticides and herbicides are used to manage pests, over-reliance on chemicals has led to resistance and environmental pollution.

3.7.7 Financial Constraints

- Limited Access to Credit: Many farmers, especially smallholders, do not have access to affordable financing. They often rely on informal credit channels, which come with high-interest rates and exploitative terms.

- Inadequate Insurance: There's a lack of proper crop insurance mechanisms to protect farmers from unpredictable losses caused by floods, droughts, or market price fluctuations.

3.7.8. Land Tenure Issues

- Fragmented Land Holdings: Many farmers do not own their land or own very small plots. This makes it difficult for them to invest in long-term improvements, such as soil health, infrastructure, or modern machinery.
- Land Ownership Disputes: Legal and administrative hurdles regarding land ownership often discourage investment in agricultural practices.

3.7.9. Market Access and Price Fluctuations

- Price Volatility: Prices for agricultural products fluctuate wildly, making it difficult for farmers to plan financially. The lack of price stabilization mechanisms can result in significant income insecurity.
- Middlemen Dominance: Middlemen often control the agricultural supply chain, leading to the exploitation of farmers. Farmers receive low prices for their produce while middlemen earn disproportionately high profits.

3.7.10. Limited Agricultural Policy Support

- Weak Policy Implementation: While the government has announced various policies aimed at boosting agriculture, there is often a disconnect between policy and its practical implementation. Corruption, lack of resources, and weak governance contribute to policy failures.
- Ineffective Subsidy Programs: Subsidies on inputs like fertilizers and seeds are often misallocated, and large landowners benefit disproportionately, leaving small farmers without the necessary support.

3.7.11. Labor Shortages

- Rural-Urban Migration: A significant proportion of rural labor is migrating to urban areas in search of better opportunities. This is leading to labor shortages in farming, especially during peak seasons like harvesting.

3.7.12. Poor Health and Nutrition

- Malnutrition: Despite being an agrarian economy, Pakistan faces widespread malnutrition, particularly in rural areas. There is a need for better food security programs and a diversified diet to improve the nutrition of the population.

3.7.13 Ways to Address These Issues:

- Water Management Reforms: Efficient irrigation systems (like drip irrigation), improving water storage, and better management of water resources are essential.
- Climate-Resilient Farming: Adopting climate-resilient crop varieties, crop diversification, and sustainable agricultural practices could help mitigate climate change's impact.
- Investment in Research and Development: More funding and focus on agricultural research can help develop high-yielding, drought-resistant crops and pest management techniques.
- Technological Adoption: Encouraging the use of modern machinery, digital platforms for weather forecasting, and precision agriculture can help boost productivity.
- Access to Credit and Insurance: Improving access to financial services, including affordable credit and crop insurance, can help farmers mitigate risks and invest in better practices.
- Infrastructure Development: Building roads, storage facilities, and better market access will help reduce post-harvest losses and improve farm-to-market efficiency.
- Addressing these problems requires a comprehensive, multi-pronged approach, involving the government, private sector, and international agencies working together to create a more sustainable, resilient agricultural system.

3.8 Self-Assessment Questions

1. Agriculture contributes around _____ to Pakistan's GDP.
2. The country’s forest area is around _____ of its total land area
3. What is _____season crop
4. Cotton is _____ season crop
5. Cutting of forest trees is major cause of _____

Answers

1) 23.54%2) 5% 3) Rabi 4) Khairf/Summer 5) Deforestation

3.9 References

1. Ahmad, K. F. Z., Muhammad, S., Ul, H. M., Tahira, G. H., Feehan, H., Amir, M. S., & Atif, W. (2013). Agricultural dynamics in Pakistan: Current issues and solutions. Russian Journal of Agricultural and Socio-Economic Sciences, 20(8), 20-26.
2. Aslam, M. (2016). Agricultural productivity current scenario, constraints and future prospects in Pakistan. *Sarhad Journal of Agriculture*, *32*(4), 289-303.
3. Azam, A., & Shafique, M. (2017). Agriculture in Pakistan and its Impact on Economy. *A Review. Inter. J. Adv. Sci. Technol*, *103*, 47-60.
4. Faruqee, R. (1995). Government's role in Pakistan agriculture: major reforms are needed (Vol. 1468). World Bank Publications.
5. Khan, I., Akram, A., Fatima, S., Ahmad, B., Rehman, Z., Arshad, N., ... & Ahmad, Z. (2022). Problems of agriculture in Pakistan: an insight into their solution. *Pakistan Journal of Biotechnology*, *19*(02), 73-83.
6. Khan, M. H., & Salam, A. (1997). Agricultural'Crisis' in Pakistan: Some Explanations and Policy Options [with Comments]. The Pakistan Development Review, 36(4), 419-466.
7. Rozema, J. (1991). Agricultural problems of saline arable land in Pakistan. In Ecological responses to environmental stresses (pp. 278-289). Dordrecht: Springer Netherlands.
8. Wright, S. J. (1951). SOME AGRICULTURAL PROBLEMS OF PAKISTAN. *Journal of the Royal Society of Arts*, *99*(4849), 573-583.

Unit: 4

CLIMATE, WEATHER AND SEASONS OF PAKISTAN

Compiled by: Dr. Muhammad Shaukat
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

Introduction:..... 47
Objectives : 47
Learning outcomes:..... 47
4.1 Introduction of Climate..... 48
4.2 Major Characteristics of Climate..... 48
4.2.1 Climate..... 48
4.2.2 Weather 48
4.2.3 Seasons..... 48
4.3 Climate Change..... 48
4.4. Impact of Climate on Crop Production..... 49
4.5 Conclusion 51
4.6 Self-Assessment Questions..... 51
4.7 References..... 52

INTRODUCTION:

Pakistan experiences a wide variety of climatic conditions due to its diverse geography, ranging from high mountains in the north to deserts in the south. Climate and weather play a vital role in shaping the country's agriculture, lifestyle, and economy. Understanding the difference between climate and weather is important, as climate refers to long-term patterns, while weather describes short-term atmospheric conditions.

Pakistan has four main seasons—winter, summer, monsoon (rainy season), and autumn—each with its own characteristics and influence on human activities, crops, and natural resources. Studying the climate, weather, and seasons of Pakistan helps us understand their impact on agriculture, water resources, and daily life, and also prepares us to deal with challenges like floods, droughts, and climate change.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the concepts of climate and weather and highlight the difference between them.
2. Describe the major climatic regions of Pakistan and their characteristics.
3. Identify and explain the four main seasons of Pakistan and their impact on people and agriculture.
4. Discuss the influence of climate and weather on crop production, water resources, and daily life.
5. Create awareness about the challenges of climate change and extreme weather events in Pakistan.
6. Encourage students to think about adaptation and mitigation strategies for sustainable living and agriculture.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. Differentiate between climate and weather with suitable examples.
2. Describe the major climatic regions of Pakistan and their features.
3. Identify and explain the four main seasons of Pakistan and their characteristics.
4. Analyze the effects of climate and seasonal changes on agriculture, water resources, and human activities.
5. Discuss the challenges posed by extreme weather events and climate change in Pakistan.

4.1 Introduction of Climate

The average pattern of weather elements such as temperature, humidity, wind, and rainfall in a region over a long period (usually 30 years or more). For example, Pakistan's climate is mostly arid to semi-arid, with regional variation from coastal to mountainous climates.

Weather: The short-term (daily or weekly) atmospheric conditions at a specific place and time. It includes changes in temperature, precipitation, humidity, and wind.

Seasons: Divisions of the year based on changes in weather, daylight, and ecology. Pakistan typically experiences: - Rabi (Winter Crop Season) – October to March - Kharif (Summer Crop Season) – April to September - Zaid – Transitional period between Rabi and Kharif

4.2 Major Characteristics of Climate

4.2.1 Climate

Climate refers to the long-term average of weather patterns. It influences crop zoning, plant growth cycles, and water availability. Types in Pakistan include arid (Sindh, Balochistan), semi-arid (Punjab), humid (Northern areas, Kashmir), and coastal (Karachi, Makran).

4.2.2 Weather

Weather includes short-term variability that affects day-to-day farming operations, pest/disease outbreaks, and heat/cold stress. Examples include unexpected rainfall damaging wheat or frost affecting orchards.

4.2.3 Seasons

Seasons govern crop calendars and water requirements. Pakistan's cropping pattern revolves around Rabi crops (e.g., wheat), Kharif crops (e.g., rice), and transitional Zaid crops.

4.3 Climate Change

Climate change is a change in the mean state of weather statistics over a three-decade time period (IPCC, 2014). This global climate change is now becoming a serious threat to the stability of societies, natural and managed ecosystems (Nema *et al.,* 2012). The rapid increase in ambient temperature and variations in rainfall patterns are mainly linked with the emission of greenhouse gases (GHGs) emission by anthropogenic activities (IPCC, 2014). Indeed, the mean global surface temperature during the last century has been increased by 0.6 °C (IPCC, 2014). Similarly, a further increase in temperature 1.4 to 5.8 °C is being expected

by the end of the current century (IPCC, 2014). This increase in average surface temperature of the globe by the end of the current century (2081–2100) in relation to 1986–2005 is probably to be 0.3 to 1.7°C for RCP2.6, while 1.1 to 2.6°C for RCP4.5 and 1.4 to 3.1°C for RCP6.0, as well as 2.6 to 4.8°C with RCP8.5. Moreover, variations in precipitation/rainfall will not be identical (IPCC, 2014).

Pakistan is in the top ten countries vulnerable to climate change (Germanwatch, 2016) as 0.57 °C rise in temperature recorded from 1961 to 2014. The agriculture industry is the most vulnerable to future climate change and variability. The accelerating pace of climate change is making the situation more severe due to the occurrence of unprecedented weather. For the last 10 years, Asia has been facing serious threats from climate change and variability, such as tsunamis, floods and droughts.

Extreme events are expected to have large negative impacts on crop productivity (Challinor et al. 2007; Wheeler et al. 2000). The most intense impacts of climate change over the next few decades will be on food and agriculture systems. Some Asian countries e.g. Pakistan and India,in semi-arid environments are at stake of rising temperature and rainfall variability, which result in increasing demand of water for agricultural production (Anwar et al. 2013). The rise in temperature and reduction in rainfall under semi-arid environments are likely to reduce production of maize, wheat, rice, and minor crops in the coming 20 years (Lobell et al. 2008). Food security will be substantially affected by these confrontational changes. Since the 1990s, increasing prices of different commodities along with decreasing cropped area per capita have caused a reduction in food productivity. It is eroding food security in many countries (Brown and Funk 2008). The identification of root causes of these changes in climate and the development of mitigation and adaptation approaches would receive high consideration in the future under developing countries.

4.4. Impact of Climate on Crop Production

A. Temperature

Optimal temperatures are crucial for germination, flowering, and fruit setting. For instance, wheat grows best at 20–25°C while rice prefers 25–30°C. High temperatures can cause flower abortion and sunburn in sensitive crops.

B. Rainfall

Rain-fed agriculture depends heavily on timely and sufficient rainfall. Uneven distribution can lead to droughts in regions like Thar or floods in Sindh and Punjab, such as those in 2022, affecting over 2.5 million hectares.

C. CO_2 Concentration

Increased CO_2 can enhance growth in C3 crops like wheat but may lead to nutrient imbalances and increased pest incidence.

D. Extreme Weather Events

Climate change is causing more frequent heatwaves, hailstorms, and unseasonal rains. In 2022, temperatures exceeded 50°C in Jacobabad.

E. Pest & Disease Incidence

Warm and humid conditions favor pest infestations such as aphids in mustard, rust in wheat, and fruit flies in mango.

F. Shifting Crop Zones

Climate shifts are pushing crops like cotton northward and reducing apple production in Balochistan due to fewer chilling hours.

4. Supporting Data (Pakistan Focus)

Factor	Statistic / Impact
Avg. Rainfall	~375 mm annually (national average)
Flood Damage 2022	>33 million people affected, >2 million hectares damaged
Temperature Rise	Avg. increase of 0.6°C since
Agriculture Share	19.2% of GDP; employs 38% of workforce (2023)
Irrigated Area	80% of the cultivated land in Pakistan

4.5 Conclusion

Climate and weather play a pivotal role in crop productivity. As climate patterns change, they bring challenges like increased pest attacks, water scarcity, and yield fluctuations. Understanding the relationship between climate and agriculture is essential for ensuring food security and adapting farming practices to sustain productivity.

4.6 Self-Assessment Questions

Fill the blanks

1. _____refers to the long-term average of weather patterns.
2. _____is a change in the mean state of weather statistics over t - three-decade time period
3. _____includes short-term variability that affects day-to-day farming operations.
4. Increased CO_2 can enhance growth in _____ crops
5. Climate of Punjab of Pakistan is _____

Answers

1) Climate 2) Climate change 3) Weather 4) C3 5) Semi-arid

4.7 References

1. Ahmed, K., Shahid, S., & Nawaz, N. (2018). Impacts of climate variability and change on seasonal drought characteristics of Pakistan. *Atmospheric research*, *214*, 364-374.
2. Abbas, S., Waseem, M., Yaseen, M., Latif, Y., Leta, M. K., Khan, T. H., & Muhammad, S. (2023). Spatial-temporal seasonal variability of extreme precipitation under warming climate in Pakistan. *Atmosphere*, *14*(2), 210.
3. Fahad, S., & Wang, J. (2020). Climate change, vulnerability, and its impacts in rural Pakistan: a review. *Environmental Science and Pollution Research*, *27*(2), 1334-1338.
4. Khan, S. (2019). Climate Classification of Pakistan: Climate Classification of Pakistan. *International Journal of Economic and Environmental Geology*, *10*(2), 60-71.
5. Khan, S., Shahab, S., Fani, M. I., Wahid, A., & Khan, A. (2021). Climate and weather condition of Balochistan province, Pakistan. *International Journal of Economic and Environmental Geology*, *12*(2), 65-71.
6. Naqvi, S. N., & Rehmat, M. (1962). Weather and climate of Pakistan. *Pakistan Geographical Review*, *17*(1), 1-18.
7. Rasul, G., & Ahmad, B. (2012). Climate change in Pakistan. Pakistan Meteorological Department.
8. Sheikh, M. M., Manzoor, N., Adnan, M., Ashraf, J., & Khan, A. M. (2009). Climate profile and past climate changes in Pakistan. *Global Change Impact Studies Center (GCISC)-RR-01*, 1-189.

Unit: 5

LAND AND WATER RESOURCES OF PAKISTAN

Compiled by: Dr. Muhammad Rehan
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

Introduction :..... 55
Objectives : 55
Learning outcomes:..... 55
5.1 Introduction..... 56
5.2 Total Reported Area 57
5.3 Forest Area 58
5.4 Area Not Available for Cultivation 59
5.5 Culturable Waste 60
5.6. Area Cultivated for Agriculture 61
5.7. Water Resources..... 62
5.8 Water Quality 63
5.9 Land and Water Use 65
5.10 Conclusion 66
5.11. Self-Assessment Questions 68
5.12 References..... 68

INTRODUCTION :

Land and water are the most valuable natural resources of Pakistan, forming the foundation of its agriculture and economy. The country has vast agricultural plains, fertile soils, and an extensive irrigation network, making it one of the largest canal-irrigated regions in the world. At the same time, Pakistan faces challenges such as soil degradation, water scarcity, salinity, and uneven distribution of resources.

Studying land and water resources is important to understand how these natural assets are used, managed, and conserved. It helps in identifying their potential for agriculture, industry, and human needs while also highlighting the issues that threaten sustainability. Proper management of land and water resources is essential for ensuring food security, economic growth, and environmental balance in Pakistan.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the importance of land and water resources for Pakistan's agriculture and economy.
2. Identify the types of land in Pakistan, including cultivated, barren, and rangelands, along with their uses.
3. Describe the sources of water such as rivers, rainfall, groundwater, and canals.
4. Highlight the irrigation system of Pakistan, particularly the Indus Basin Irrigation System.
5. Discuss the problems related to land and water resources, including soil erosion, salinity, waterlogging, and scarcity.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. **Describe** the significance of land and water resources for Pakistan's agriculture and economy.
2. **Classify** different types of land in Pakistan and explain their uses in farming and other activities.
3. **Identify and explain** the main sources of water, including rivers, canals, groundwater, and rainfall.
4. **Illustrate** the structure and functioning of the Indus Basin Irrigation System.
5. **Analyze** the major problems related to land and water resources, such as salinity, waterlogging, soil erosion, and scarcity.

5.1 Introduction

Pakistan's economy is deeply rooted in agriculture, which forms the backbone of the nation's rural livelihoods, food security, and industrial base. As of the Economic Survey of Pakistan (2024-25), agriculture contributes around 23.5% to the national Gross Domestic Product (GDP) and supports over 38% of the labor force, primarily in rural areas. Beyond direct employment, agriculture also sustains allied sectors such as food processing, textile manufacturing, fertilizer and pesticide industries. A significant share of export earnings is derived from agricultural products, especially cotton, rice, fruits, and vegetables.

Given this economic structure, the sustainability and productivity of land and water resources are of paramount importance. Land and water are the primary natural capital upon which Pakistan's agricultural development depends. However, the country faces mounting challenges in managing these resources efficiently and equitably. Rapid population growth, now exceeding 241 million people, along with accelerated urbanization and industrialization, has intensified pressure on finite land and water assets. Per capita agricultural land has decreased, and competition among agricultural, urban, and industrial land uses has heightened.

Furthermore, climate change has emerged as a serious threat to water security and land productivity. Pakistan is ranked among the top ten most climate-vulnerable countries globally. Increasing temperatures, erratic rainfall patterns, shrinking glaciers, frequent droughts, and extreme flooding events have all negatively impacted land and water resources. Simultaneously, groundwater depletion, salinization, deforestation, and inefficient irrigation techniques have exacerbated land degradation and water stress.

This unit offers a comprehensive analysis of the state of land and water resources in Pakistan. It explores the types, extent, and condition of land and water, including total reported area, forest cover, non-cultivable land, cultivable waste, and agricultural land. It also assesses the country's surface and groundwater resources, water quality issues, and the patterns and efficiency of land and water use in agriculture.

Emphasis is placed on identifying the underlying causes of resource degradation and evaluating strategies for conservation, restoration, and sustainable use. Scientific knowledge, policy frameworks, and emerging technologies are integrated to provide a multidisciplinary approach to land and water management. By doing so, this unit aims to equip students, practitioners, and policymakers with the conceptual tools and practical insights needed for responsible resource governance in the face of demographic, environmental, and socio-economic pressures.

Ultimately, strengthening the stewardship of land and water resources is essential not only for sustaining agricultural productivity but also for fostering resilience to climate change, preserving biodiversity, and achieving long-term sustainable development goals in Pakistan.

5.2 Total Reported Area

Pakistan has a total geographical area of around 88 million hectares (Mha), of which the officially reported area under land records is 79.61 Mha. This vast territory encompasses diverse physiographic zones, including the Himalayan mountains in the north, the Balochistan Plateau in the west, the fertile Indus River plain in the center, and arid deserts in the south and southeast. The remaining 8.39 Mha remains unreported in official land records, largely due to the challenging topography of mountainous regions like Gilgit-Baltistan, the remoteness and administrative limitations in tribal and border areas such as parts of Khyber Pakhtunkhwa and Balochistan, and the complexities arising from disputed territories, particularly in the Kashmir region. The reported area of 79.61 Mha is systematically categorized based on land use characteristics. These include land under forests, land not available for cultivation (such as urban infrastructure, rocky terrain, and desert lands), culturable waste (land suitable but not currently used for farming), and net sown or cultivated area (land actively used for crop production). This classification is crucial for resource allocation, policy formulation, and targeted development planning.

Category	Area (Mha)	Percentage (%)
Total Reported Area	79.61	100
Forests	4.46	5.6
Not Available for Cultivation	23.10	29.0
Culturable Waste	8.15	10.2
Net Sown Area	22.00	27.6
Current Fallow	5.60	7.0
Total Cropped Area	27.60	34.6

(Source: Pakistan Bureau of Statistics, 2025)

These figures underline the fact that a substantial portion of the country's land is either uncultivable or underutilized. With rapid population growth and urban

expansion, pressure on cultivable land is increasing, leading to land fragmentation, reduced per capita land availability, and increased competition among land uses. The spatial distribution of these land categories varies significantly across provinces. For example, Punjab dominates in terms of cultivated land, whereas Balochistan holds the largest area of cultivable waste due to its arid conditions and sparse population. A comprehensive regional approach is necessary to bring unused land into productive use while ensuring environmental sustainability.

5.3 Forest Area

Forests are essential for maintaining ecological balance, regulating the climate, preserving biodiversity, protecting watersheds, and supporting the livelihoods of millions of people, especially in forest-adjacent rural communities. In the context of climate change, forests also serve as crucial carbon sinks that help mitigate greenhouse gas emissions and enhance climate resilience.

However, the forest cover in Pakistan is alarmingly low—only about 4.46 million hectares (Mha), which represents approximately 5.6% of the total reported land area. This figure is among the lowest in the world when compared to the global average forest cover of around 31%, and even lower than the recommended minimum of 20-25% for ecological stability in a country. This deficit reflects historical underinvestment in forestry, overexploitation of forest resources, and competing land use demands.

Pakistan's forests are classified into several ecological types:

- **Coniferous forests** (northern KP, Gilgit-Baltistan, and AJK): Rich in timber species like deodar and blue pine.
- **Tropical thorn forests** (Punjab, Sindh, Balochistan): Characterized by hardy species such as Acacia and Prosopis.
- **Riverine forests** (along the Indus River): Provide flood protection and wood resources, but are rapidly declining.
- **Scrub forests** (Potohar Plateau): Used extensively for grazing and fuelwood.
- **Mangrove forests** (Indus Delta in Sindh): Provide critical habitat for marine biodiversity and protect coastlines from erosion and cyclones.

Despite their ecological and economic value, Pakistan’s forests face serious threats from deforestation, illegal logging, overgrazing, encroachment for agriculture, and unregulated infrastructure development. It is estimated that Pakistan has been losing forest cover at a rate of 27,000 hectares per year (FAO,

2023). The conversion of forestland for agriculture and settlement, coupled with weak enforcement of forest protection laws, has further exacerbated degradation.

To reverse deforestation trends, several initiatives have been introduced, including:

- **Billion Tree Tsunami (Khyber Pakhtunkhwa)**: Successfully reforested over 350,000 hectares.
- **Ten Billion Tree Tsunami Program (TBTTP)**: A national-level reforestation drive launched in 2019, aiming to restore forest ecosystems and increase green cover. As of 2024, over 1.8 billion saplings have been planted across the country.
- **REDD+ Program (Reducing Emissions from Deforestation and Forest Degradation)**: In collaboration with international partners to promote carbon financing and sustainable forest management.

Additionally, efforts are being made to involve local communities in forest management through Joint Forest Management (JFM) approaches, promote agroforestry systems on farmlands, and introduce modern forest inventory and monitoring systems using satellite-based remote sensing.

Given the growing climate challenges and biodiversity loss, it is imperative for Pakistan to expand its forest cover, rehabilitate degraded forestlands, and integrate forestry in national development and climate action plans.

5.4 Area Not Available for Cultivation

This category includes land under mountains, deserts, urban settlements, roads, infrastructure, and bodies of water. As of 2025, approximately 23.10 Mha (29% of the reported area) falls under this classification. Much of this land is permanently non-arable due to natural constraints like steep slopes, stony soils, and extreme aridity.

However, some of these lands, especially those that have been lost to urban sprawl, represent a concerning trend. In peri-urban areas of major cities like Lahore, Karachi, and Islamabad, highly fertile agricultural land is rapidly being converted for housing schemes, industrial zones, and transportation corridors. According to the Urban Unit (2024), nearly 0.5 Mha of prime agricultural land has been lost to non-agricultural use over the past decade.

Land-use planning remains weak across provinces, and coordination between agricultural, housing, and environmental departments is often lacking. Strengthening land zoning regulations, enforcing green belts, and incentivizing vertical development in cities are potential solutions to reduce pressure on agricultural land.

5.5 Culturable Waste

Culturable waste refers to land that is suitable for cultivation but is currently not being utilized for crop production. Pakistan's cultivable waste is estimated at 8.15 million hectares, a significant proportion that represents untapped potential for increasing agricultural output and food security.

This land remains unused due to a variety of constraints, including:

- Inadequate irrigation infrastructure
- Water scarcity or poor water quality
- Soil salinity and sodicity
- Lack of access to farm inputs and credit
- Absence of land development programs
- Legal and ownership disputes

Provincial distribution of culturable waste is uneven, with Balochistan accounting for the largest share due to its arid climate and sparse population. Punjab and Sindh have comparatively lower levels of cultivable waste, but still contain substantial areas that could be brought under cultivation with appropriate interventions.

Efforts to utilize culturable waste have included:

- Gypsum application for reclaiming saline-sodic soils
- Construction of small dams and check dams in hilly areas
- Laser land leveling and land grading
- Promotion of drought-resistant and salt-tolerant crop varieties
- Infrastructure development (e.g., rural roads and irrigation channels)

The Punjab Irrigated Agriculture Productivity Improvement Project (PIPIP) and Barani Area Development Project are examples of targeted initiatives aimed at bringing cultivable waste into productive use through irrigation and land improvement techniques. Expansion of these programs to other provinces could yield significant agricultural benefits.

Future strategies should focus on:

- Mapping and classification of culturable waste using GIS and satellite imagery
- Integrated land and water resource planning

- Strengthening extension services to support land reclamation
- Public-private partnerships to finance land development

Bringing even a fraction of culturable waste into productive use could significantly increase national crop production, enhance rural livelihoods, and contribute to economic stability.

5.6. Area Cultivated for Agriculture

Agricultural land in Pakistan is classified into net sown area and current fallow land. As of 2025, the net sown area is about 22 million hectares, while 5.6 million hectares lie fallow during any given season. Together, these constitute a total cultivated area of 27.6 million hectares. The cropping intensity, the ratio of total cropped area to net sown area, stands at approximately 143%, reflecting multiple cropping practices in fertile zones, especially in Punjab.

Province	**Net Sown Area (Mha)**	**Cropping Intensity (%)**
Punjab	12.3	160
Sindh	5.2	130
Khyber Pakhtunkhwa	1.5	115
Balochistan	2.1	90

(Source: Ministry of National Food Security and Research, 2025)

Multiple cropping systems such as wheat-rice, wheat-maize, and cotton-wheat dominate in canal-irrigated areas. Rainfed areas, primarily in Potohar and parts of KP, experience lower cropping intensities due to reliance on erratic rainfall.

The following is practiced to conserve soil moisture, particularly in rainfed regions, or due to a lack of resources to grow a second crop. However, fallow land represents an opportunity for agricultural intensification if supported by improved water availability and soil management.

Sustainable intensification strategies include:

- Integrated soil fertility management
- Use of short-duration and drought-tolerant crops
- Improved seed varieties and mechanization
- Adoption of conservation agriculture (CA) techniques

The key to increasing productivity lies in transitioning from extensive to intensive and resource-efficient farming systems that can optimize yield per unit of land and water.

5.7. Water Resources

Pakistan's water resources are primarily dependent on two major sources: surface water and groundwater. The Indus River System is the main source of surface water, contributing over 90% of the total freshwater supply used for agriculture, industry, and domestic consumption. The river system comprises the Indus River and its five major tributaries: Jhelum, Chenab, Ravi, Beas, and Sutlej, originating mainly from the Himalayan and Karakoram ranges. These rivers form one of the world's largest contiguous irrigation networks, the Indus Basin Irrigation System (IBIS).

In addition to river flows, the country receives an average annual rainfall of approximately 300 mm, but this is highly uneven and seasonal, with significant spatial variation between the arid regions of Balochistan and the humid zones of the northern highlands. The seasonal concentration of rainfall during the monsoon (July–September) further complicates water storage and availability.

Water Source	**Average Annual Availability (MAF)**
Surface Water (Indus System)	140
Groundwater	55
Rainfall (Utilizable)	15
Total	210

(Source: PCRWR, 2024)

Per capita water availability in Pakistan has declined sharply from 5,600 cubic meters in 1951 to less than 1,000 cubic meters in 2025, placing the country in the category of "water scarce" nations (World Bank, 2025). This dramatic decline is attributed to rapid population growth, urban expansion, and growing water demand in agriculture and industry.

The mismatch between supply and demand is worsened by seasonal variability. More than 80% of river flows occur during the monsoon months, whereas water demand peaks during the Rabi season (October to March), especially for wheat and other winter crops. However, Pakistan's water storage capacity is limited to just 30 days of average river flows, compared to 200 days in India. This

insufficient storage makes the country vulnerable to droughts, floods, and water shortages.

Major reservoirs and barrages supporting water regulation and storage include:

- **Tarbela Dam** on the Indus River – ~9 MAF storage
- **Mangla Dam** on the Jhelum River – ~7 MAF storage
- **Diamer-Bhasha Dam** (under construction) – Expected storage ~8 MAF

These reservoirs play a crucial role in managing seasonal flows, generating hydroelectric power, and supplying irrigation water. However, sedimentation and aging of infrastructure have reduced their effective capacity.

The Indus Waters Treaty (1960), a landmark agreement between Pakistan and India-allocates the western rivers (Indus, Jhelum, Chenab) to Pakistan and the eastern rivers (Ravi, Beas, Sutlej) to India. While the treaty has survived several conflicts, new challenges such as climate change, glacial retreat, and growing water demand are testing its long-term sustainability.

Emerging threats include:

- **Rapid glaciers melt** in the Hindu Kush-Himalayan region
- **Changing monsoon patterns** are affecting river inflows
- **Water disputes with India** over upstream hydropower projects
- **Inadequate transboundary water governance frameworks**

To address these issues, Pakistan needs to strengthen water governance, enhance storage infrastructure, invest in water-efficient technologies, and modernize data collection and forecasting systems.

Integrated watershed management, improved reservoir operations, and regional cooperation under platforms like the South Asia Water Initiative (SAWI) can help promote sustainable water use and climate resilience.

5.8 Water Quality

The quality of Pakistan's surface and groundwater resources has deteriorated significantly over recent decades, posing a critical threat to public health, agricultural productivity, and environmental sustainability. Contamination of water sources stems from multiple anthropogenic activities, including unregulated agricultural practices, unchecked industrial discharges, and poor municipal waste management.

Key pollutants affecting water quality in Pakistan include:

- **Agricultural runoff:** Excessive use of fertilizers and pesticides contributes to nutrient loading (nitrates, phosphates) in water bodies, causing eutrophication and harmful algal blooms.
- **Industrial effluents:** Untreated discharge from textile, leather, paper, and chemical industries introduces heavy metals and toxic organic compounds into rivers and canals.
- **Municipal sewage:** Over 90% of municipal wastewater in Pakistan is discharged without treatment, leading to severe bacterial contamination (including E. coli and coliforms).
- **Saline intrusion:** In coastal and groundwater-dependent regions, over-extraction and seawater intrusion degrade water quality, particularly in Sindh and southern Punjab.

Groundwater contamination is a growing concern in urban and peri-urban areas. Studies by the Pakistan Council of Research in Water Resources (PCRWR) reveal that major cities such as Lahore, Quetta, and Hyderabad exhibit elevated concentrations of:

- **Total dissolved solids (TDS):** Often exceeding WHO permissible limits.
- **Nitrates:** Linked to fertilizer overuse, causing methemoglobinemia ("blue baby syndrome") in infants.
- **Heavy metals:** Arsenic, lead, and chromium contamination pose chronic health risks.
- **Microbial pathogens:** Fecal coliforms and E. coli are indicators of sewage pollution, commonly found in shallow wells.

According to PCRWR (2024), over **70% of drinking water sources in rural Pakistan are unsafe** due to poor sanitation, the absence of filtration, and contamination from agricultural and animal waste. Unsafe irrigation water also affects crop quality and poses risks to food safety.

To address the growing water quality crisis, Pakistan must undertake a multi-pronged strategy:

- **Enforce National Environmental Quality Standards (NEQS):** Ensure industries treat wastewater before discharge and adopt cleaner production practices.
- **Expand wastewater treatment infrastructure:** Construct decentralized and low-cost treatment plants in urban and rural areas.

- **Promote precision agriculture:** Encourage efficient nutrient and pesticide management through soil testing, drip fertigation, and integrated pest management (IPM).
- **Raise community awareness:** Implement nationwide campaigns on water conservation, hygiene, and safe water practices in schools and rural communities.

Strengthening institutional coordination among the Ministry of Climate Change, the Ministry of Water Resources, and provincial environmental protection agencies is essential for monitoring and regulating water quality. Investments in real-time water quality monitoring systems and laboratory networks will improve data availability and policy response.

Improving water quality is not just a health and environmental priority, but also an economic necessity. Safe and reliable water supplies are fundamental to achieving sustainable development, agricultural resilience, and improved quality of life for millions of Pakistanis.

5.9 Land and Water Use

Pakistan's agriculture consumes nearly 93% of the total available freshwater, yet irrigation efficiency is among the lowest globally. Traditional flood irrigation methods, which dominate over 80% of irrigated lands, lead to excessive water losses through evaporation, seepage, and deep percolation. These practices not only waste water but also cause secondary problems such as waterlogging, salinization, and soil degradation-particularly in the Indus Basin Irrigation System (IBIS).

The imbalance between supply and demand, combined with aging infrastructure and poor water governance, creates substantial inequities and inefficiencies in water distribution. Tail-end farmers often receive less water, while head-reach farmers may overuse it due to a lack of regulation and volumetric pricing.

Key challenges in land and water use include:

Inefficient irrigation practices: Predominantly flood irrigation with limited adoption of modern methods.

Canal water losses: Estimated at around 40% due to seepage, leakage, and unauthorized diversions.

Groundwater over-extraction: Especially in Punjab, where tube wells exceed 1.2 million; this has led to falling water tables and increased pumping costs.

Inequitable water distribution: Lack of transparency and poor governance in irrigation scheduling.

Poor maintenance of irrigation infrastructure: Silting, seepage, and structural decay reduce canal conveyance efficiency.

Government efforts and projects include:

National Water Policy (2018): A comprehensive framework promoting integrated water resource management (IWRM), emphasizing efficient, equitable, and sustainable use of water across sectors.

Command Area Development Programs: Aimed at improving water use efficiency by enhancing farm-level infrastructure.

Irrigation Management Transfer (IMT): Encouraging participatory irrigation management by transferring control to farmer organizations (FOs) and Area Water Boards (AWBs).

Technological solutions being promoted:

Drip and sprinkler irrigation systems: Especially for high-value crops, fruits, and vegetables in water-scarce regions.

Lining of watercourses: Reduces seepage losses and improves water conveyance.

Smart irrigation scheduling using ICT tools: Tools like Soil Moisture Sensors (SMS) and decision support systems (DSS) enable precision water application.

Water user associations (WUAs): Promote local accountability and equitable distribution of water.

To achieve sustainable agricultural growth, Pakistan must transition to climate-smart and water-efficient farming systems. Integrated land and water management linking soil health, crop planning, irrigation scheduling, and drainage can significantly enhance water productivity. Moreover, adaptive governance structures, capacity building for farmers, and incentives for efficient practices are essential for long-term resilience.

Given the country's vulnerability to climate change and increasing competition for water among domestic, industrial, and agricultural sectors, efficient and equitable land and water use is a national imperative for food security, rural development, and environmental sustainability.

5.10 Conclusion

Land and water resources are foundational to Pakistan’s agricultural economy and overall development. Agriculture continues to employ a significant share of the workforce and contributes substantially to GDP, food security, and rural livelihoods. However, these vital resources are increasingly under threat from a

combination of factors, including population pressure, urban encroachment, climate variability, environmental degradation, and institutional weaknesses.

Despite having a vast expanse of cultivable land and a historically rich river system, Pakistan is not fully capitalizing on its resource potential. A large portion of culturable waste remains unused, forest areas continue to shrink, and irrigation practices remain inefficient. Water quality is deteriorating due to untreated waste and excessive agrochemical use, while poor land use planning contributes to deforestation, soil erosion, and land degradation. The consequences of these challenges are visible in declining per capita water availability, reduced agricultural productivity, and increased vulnerability to natural disasters.

To address these issues and build a sustainable agricultural future, Pakistan must prioritize integrated land and water resource management. This involves:

- **Investment in water infrastructure and storage**: Building new reservoirs, rehabilitating canals, and improving on-farm water management.
- **Adoption of modern irrigation techniques**: Promoting drip, sprinkler, and other water-saving technologies.
- **Reforestation and watershed management**: Expanding Forest cover, protecting watersheds, and restoring degraded ecosystems.
- **Legislative reforms**: Developing and enforcing policies related to land tenure, land zoning, water rights, and environmental protection.
- **Community involvement and capacity building**: Encouraging participatory planning, farmer education, and local water user associations.

Moreover, climate change adaptation must be integrated into all land and water policies. Improved data collection, early warning systems, and regional cooperation on water-sharing are equally critical. Public-private partnerships, research and innovation, and alignment with Sustainable Development Goals (SDGs) will play a vital role in this transformation.

With coordinated efforts from policymakers, scientists, extension workers, farmers, and civil society, Pakistan can restore the productivity, resilience, and sustainability of its land and water resources. Doing so is essential not only for food security and rural prosperity but also for achieving broader environmental and economic sustainability in the decades ahead.

5.11. Self-Assessment Questions

Fill the blanks

1. The total reported area of Pakistan is _____
2. Per capita water availability in Pakistan is less than cubic meters per person in 2025
3. _____of the total reported area is not available for cultivation
4. Land that is suitable for cultivation but currently is not under cultivation is known as_____.
5. _____ dam is built on the Indus River

Answers

1) 79.61 million hectare 2) 1,000 3) 29.0% 4) Culturable waste 5) Tarbela Dam

5.12 References

1. Food and Agriculture Organization of the United Nations. (2023). *AQUASTAT country profile: Pakistan*. FAO.
2. Ministry of Climate Change. (2024). *National report on forests and afforestation*. Government of Pakistan.
3. Ministry of Finance. (2024–2025). *Economic survey of Pakistan 2024–25*. Government of Pakistan.
4. Ministry of Water Resources. (2018). *National water policy*. Government of Pakistan.
5. Pakistan Bureau of Statistics. (2025). *Land utilization statistics*. Government of Pakistan.
6. Pakistan Council of Research in Water Resources. (2024). *Annual report 2024*. PCRWR.
7. Urban Unit Punjab. (2024). *Land use and urban expansion report*. Government of Punjab.
8. World Bank. (2025). *Water security and climate change in South Asia*. World Bank Group.
9. WWF-Pakistan. (2024). *Forest status and conservation trends*. WWF-Pakistan.

Unit: 6

CROP NUTRITION

Compiled by: Dr. Riffat Sultana
Reviewed by: Dr. Sabir Hussain Shah

CONTENTS

Introduction :..... 72
Objectives : 72
Learning outcomes:..... 72
6.1 Introduction..... 73
6.2 Essential Plant Nutrients..... 75
6.2.1 Primary Nutrients..... 76
6.3 Nitrogen (N)..... 76
6.3.1 Importance in Plant Growth..... 76
6.3.2 Sources and Availability 76
6.3.3 The Nitrogen Cycle..... 77
6.3.4 Biological Role of Nitrogen..... 77
6.3.5 Nitrogen Losses from Soil 77
6.3.6 Ammonium/Nitrate Ratio..... 78
6.3.7 Ammonium/Nitrate Ratio and Its Importance..... 78
6.3.8 Metabolism and Transport Differences..... 78
6.3.9 Temperature Effects 78
6.3.10 Nutrient Competition and pH Impact 79
6.4 Phosphorus (P)..... 79
6.4.1 Functions of Phosphorus in Plants..... 79
6.4.2 Phosphorus in Plant Tissues..... 79
6.4.3 Phosphorus in Soil 80
4.4 Key Points on Soil Phosphorus Behavior..... 80
6.4.4 Phosphorus Deficiency 80
6.4.5 Phosphorus Excess..... 80
6.5 Potassium (K)..... 81
6.5.1 Key Functions of Potassium in Plant Growth..... 81

6.5.2 The Role of Potassium in Plant Growth and Development 81
6.5.3 Potassium Deficiency in Plants: Symptoms and Effects 82
6.5.4 Other symptoms include: 82
6.5.5 Factors Influencing Potassium Uptake in Plants 82
6.5.6 Forms of Potassium in Soil 83
6.6. Importance of Manures 83
6.7. Classification of Manures and Fertilizers 84
6.7.1 Manures: 84
6.8 Green Manuring: 86
6.8.1 Green Manure Crop:. 86
6.8.2 Types of Green Manuring 86
6.8.3 Advantages of Green Manuring 86
6.8.4 Disadvantages of Green Manuring 87
6.9 Characters of a Good Green Manuring Crop 87
6.10. Self-Assessment Questions 88
6.11 Refrence 88

INTRODUCTION :

Crop nutrition is one of the most important aspects of agriculture because healthy crops depend on a balanced supply of nutrients. Plants require essential nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur, along with micronutrients like zinc, iron, and manganese, for proper growth and development. These nutrients play a vital role in processes like photosynthesis, root development, flowering, and grain formation.

Understanding crop nutrition helps farmers use soil and fertilizers more effectively, improve crop yields, and maintain soil fertility. It also prevents problems caused by nutrient deficiencies or excesses. By studying crop nutrition, students learn how to ensure sustainable farming practices that increase food production while protecting the environment.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the importance of crop nutrition for healthy plant growth and higher yields.
2. Identify the essential nutrients required by plants and their specific roles in growth and development.
3. Distinguish between macronutrients and micronutrients and understand their sources.
4. Describe the symptoms of nutrient deficiencies and toxicities in different crops.
5. Highlight the role of fertilizers, organic matter, and soil management in maintaining plant nutrition.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. Explain the importance of crop nutrition in plant growth, development, and yield improvement.
2. Identify and classify essential plant nutrients into macronutrients and micronutrients.
3. Describe the specific functions of key nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur.
4. Recognize common deficiency and toxicity symptoms in different crops.
5. Apply knowledge of fertilizers, organic matter, and soil amendments to improve crop nutrition.
6. Analyze soil and plant nutrient requirements through soil testing and observation.

6.1 Introduction

A thorough grasp of crop nutrition is essential for enhancing plant growth and achieving maximum yields. This requires knowledge of the key nutrients that plants require, their physiological roles, and effective strategies for managing them. A PDF guide on crop nutrition would typically explore topics such as identifying essential plant nutrients (both macronutrients and micronutrients), understanding their functions within plant systems, recognizing deficiency symptoms, and implementing nutrient management practices like fertilization techniques and soil analysis.

Soil is a dynamic and complex system, often described as a living organism in its own right. It serves as a vital habitat for an intricate web of life, including plants, animals, and countless microorganisms. These organisms interact in diverse and interdependent ways, forming a rich ecosystem beneath our feet. The presence or absence of essential nutrients in the soil plays a critical role in shaping agricultural systems and determining their productivity and sustainability.

A solid understanding of crop nutrition is vital for improving production yield, enhancing crop quality, and increasing farm profitability. This includes knowing which nutrients are essential for plant growth, how they function, and the best ways to manage them. A crop nutrition guide typically covers the roles of macronutrients and micronutrients, how to identify deficiency symptoms, and practical approaches to nutrient management through fertilization plans and soil testing.

- Plants absorb nutrients primarily through two structures: roots and leaves. While the leaves take in carbon dioxide from the air, the roots absorb all other essential nutrients from the soil.
- Carbon dioxide serves as the fundamental building block for organic compounds in plants. It is absorbed through the stomata (tiny openings) in the leaves and plays a crucial role in the production of sugars and carbohydrates like starch.
- Mineral nutrients are absorbed by plant roots through two main processes. The first involves the uptake of water that carries dissolved nutrients. The second is the direct absorption of nutrient ions from the soil, a process that requires significant energy.
- For ion absorption to occur efficiently, the roots must receive photosynthates such as ATP and sugars, and there must be adequate oxygen available in the root zone.

- Additionally, plants can take in large, complex molecules such as hormones and vitamins directly from the soil. This occurs through specialized protein-lined openings in the root surface, which selectively allow specific molecules to enter at designated sites.
- CEC, or Cation Exchange Capacity, refers to the number of negative charges present on the surface of soil particles. It indicates the soil's ability to hold onto positively charged nutrients, known as cations.
- This capacity is a key factor in determining how much and how often fertilizers need to be applied, as it reflects the soil's potential to retain essential plant nutrients.
- Negatively charged surfaces are found primarily on clay particles and organic matter. These surfaces attract and hold cations—such as potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), aluminum (Al^{3+}), and hydrogen (H^+)—through electrostatic forces. Despite these interactions, the overall charge of the soil remains neutral.
- These positively charged nutrients are called **exchangeable cations** because they can be replaced by other cations present in the soil solution. While only a small fraction of nutrients exists in the soil solution at any time, the exchangeable cations attached to soil particles serve as a reservoir. This reservoir helps replenish nutrients as plants absorb them from the solution, making CEC a vital component of soil fertility.
- Plant-essential minerals are grouped into three main categories:

Cations (positively charged ions) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+)

Anions (negatively charged ions), including nitrogen (N), phosphorus (P), and sulfur (S)

Trace minerals, which are required in small quantities but are vital for plant health

- Soil fertility refers to the soil's ability to supply essential nutrients in the right amounts and balance to support healthy plant growth.
- The primary nutrients that plants need in large quantities—called **macronutrients**—are nitrogen (N), phosphorus (P), potassium (K), and sulfur (S).
- As organic matter decomposes in the soil, it releases key nutrients like nitrogen, phosphorus, and sulfur. Additionally, organic matter is one of the

main sources of Cation Exchange Capacity (CEC) in the soil, alongside clay particles.

- CEC refers to the soil's ability to hold onto positively charged nutrients (such as Ca^{2+}, Mg^{2+}, and K^{+}) and make them available to plants. A higher CEC means the soil can store more nutrients and release them gradually, supporting better plant growth.
- Soil water also plays a crucial role in nutrient management. It not only supports all life but also acts as a medium for dissolved nutrients, making them accessible for plant uptake.
- In nutrient management, soil aeration plays a vital role in the availability of various nutrients. Many microorganisms that help release nutrients for plant use depend on adequate soil air. Therefore, maintaining a proper balance between soil air and soil water is essential, as excessive water can displace the air needed for microbial activity.

Balanced Nutrition

- Plants require a balanced supply of nutrients, as some elements can compete with each other during uptake. Maintaining proper nutrient ratios is key to preventing deficiencies.
- For instance, excessive potassium can hinder the absorption of calcium and magnesium.
- Similarly, a high iron-to-manganese ratio may lead to manganese deficiency, while elevated sulfur levels can reduce nitrate uptake.

6.2 Essential Plant Nutrients

- Plants require 18 essential chemical elements for healthy growth: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), boron (B), zinc (Zn), molybdenum (Mo), nickel (Ni), copper (Cu), cobalt (Co), and chlorine (Cl).
- Carbon dioxide (CO_2) and oxygen gas (O_2) from the air supply plants with carbon and oxygen, while the remaining nutrients are primarily absorbed from the soil.
- Plant growth proceeds normally until the supply of an essential nutrient becomes limited. A deficiency in any one of these elements cannot be compensated for by other inputs. This principle is known as Liebig's *Law of the Minimum*, which states that crop yield is determined by the nutrient in shortest supply.

- Nutrient availability is affected by factors such as soil pH and the amount of organic matter.
- Nutrients required in larger quantities—carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur—are termed **macronutrients**.
- Those needed in smaller quantities, but still essential, are called **micronutrients**.

6.2.1 Primary Nutrients

- The three primary nutrients, Nitrogen (N), Phosphorus (P), and Potassium (K) are often highlighted on fertilizer packaging as N-P-K ratios.
- These nutrients are typically deficient in many soils, making them the most frequently applied in agriculture. They are used in larger quantities than secondary or micronutrients due to their vital role in plant growth.

6.3 Nitrogen (N)

6.3.1 Importance in Plant Growth

- Nitrogen is critical for vegetative growth and cell division.
- It is a major component of chlorophyll, essential for photosynthesis.
- It combines with carbon, hydrogen, oxygen, and sulfur to form amino acids, the building blocks of proteins.
- Nitrogen is involved in enzyme production, vitamin synthesis, and carbohydrate metabolism.
- It enhances leafy growth in vegetables and protein content in grain crops.
- Among all essential nutrients, nitrogen is often the most limiting factor in crop production.

6.3.2 Sources and Availability

- Nitrogen in soil mostly exists in organic forms (e.g., proteins in residues and manure), which are not directly available to plants.
- Plants absorb nitrogen only in its inorganic forms: ammonium (NH_4^+) and nitrate (NO_3^-).
- Microorganisms are essential for converting organic nitrogen into plant-available forms through a process called mineralization.

- Only about 2–3% of organic nitrogen becomes available to plants each year.
- Environmental conditions such as temperature, moisture, soil aeration, and pH affect mineralization. It occurs most efficiently at 30°C and in neutral to slightly acidic soils.

6.3.3 The Nitrogen Cycle

- Atmospheric nitrogen (N_2) makes up about 78% of the Earth's atmosphere but is unusable by most plants.
- Nitrogen fixation converts N_2 into usable forms (e.g., ammonia) via:
    - Lightning
    - Free-living bacteria
    - Symbiotic bacteria like *Rhizobium*, which live in the root nodules of legumes (peas, beans), form a mutualistic relationship by exchanging ammonia for carbohydrates.
- Planting legumes improves nitrogen levels in nutrient-poor soils.
- Small amounts of usable nitrogen also enter the soil through rainfall.

6.3.4 Biological Role of Nitrogen

- Nitrogen is found in all amino acids, proteins, nucleic acids (DNA & RNA), and chlorophyll.
- It plays a central role in the plant's photosynthetic process and overall development.
- It is a fundamental part of soil organic matter and is required in large amounts for optimal plant growth.

6.3.5 Nitrogen Losses from Soil

1. **Leaching**
    - Nitrate (NO_3^-), being water-soluble and not strongly held by soil particles, can move with water beyond the root zone, making it unavailable to plants.

2. **Volatilization**
    - Nitrogen may be lost as ammonia gas (NH_3), especially when urea-based fertilizers are surface-applied without incorporation into the soil.

3. **Denitrification**

   - Under saturated or waterlogged conditions, certain bacteria convert nitrate (NO_3^-) into gaseous nitrogen (N_2 or N_2O), which escapes into the atmosphere.

6.3.6 Ammonium/Nitrate Ratio

Nitrogen is a fundamental component of amino acids, proteins, and chlorophyll. Plants absorb nitrogen primarily in two forms: **nitrate (NO_3^-)** and **ammonium (NH_4^+)**. As a result, total nitrogen uptake by plants typically involves a combination of both forms.

6.3.7 Ammonium/Nitrate Ratio and Its Importance

The balance between **ammonium (NH_4^+)** and **nitrate (NO_3^-)** in the root zone is highly significant, influencing both **plant health** and **soil or growing medium conditions.**

- Different **plant species** require different ammonium/nitrate ratios for **optimal nutrient uptake and growth.**
- The ideal ratio also depends on several **environmental and physiological factors,** including:
  - **Temperature**
  - **Plant growth stage**
  - **Root zone pH**
  - **Soil or substrate properties**

6.3.8 Metabolism and Transport Differences

- **Ammonium** is metabolized directly in the roots, where it combines with sugars transported from the leaves. This process **requires more oxygen** than nitrate metabolism.
- **Nitrate,** in contrast, is transported to the leaves, where it is first reduced to ammonium before reacting with sugars.

6.3.9 Temperature Effects

- At **higher temperatures,** plant respiration increases, leading to faster sugar consumption and reduced sugar availability in the roots.

- Additionally, **oxygen solubility in water decreases** as temperatures rise, limiting the oxygen needed for ammonium metabolism.
- As a result, it is advisable to **reduce the ammonium/nitrate ratio** under high-temperature conditions.

6.3.10 Nutrient Competition and pH Impact

- Ammonium, being a **positively charged ion (cation),** competes with other cations, **potassium (K^+), calcium (Ca^{2+}),** and **magnesium (Mg^{2+})** for uptake by plant roots.
    - High ammonium levels can lead to **calcium and magnesium deficiencies**, although potassium uptake is typically less affected.
- Furthermore, the ammonium/nitrate ratio can influence **pH levels in the rhizosphere** (root zone). These pH shifts can affect the **solubility and availability of other essential nutrients**.

6.4 Phosphorus (P)

Phosphorus is an essential macronutrient that plays a key role in plant development, particularly during early growth stages and reproductive processes.

6.4.1 Functions of Phosphorus in Plants

- Promotes early root formation and overall root growth.
- Essential for photosynthesis, respiration, energy storage, and transfer (via ATP and ADP).
- Involved in cell division, enlargement, and the formation of DNA and RNA, which carry genetic information.
- Critical for flower initiation, seed development, and fruit quality.
- Improves maturity rate, water-use efficiency, and helps plants withstand cold or stressful conditions.
- Supports disease resistance in some plant species.

6.4.2 Phosphorus in Plant Tissues

- Seeds contain the highest phosphorus concentration in mature plants.
- Young, actively growing tissues such as shoots and root tips require large amounts of phosphorus due to high metabolic activity and rapid cell division.

6.4.3 Phosphorus in Soil

Phosphorus exists in both organic and inorganic (mineral) forms in soil. However, its solubility is low, and only a small fraction is available in the soil solution—the form that plants can absorb.

4.4 Key Points on Soil Phosphorus Behavior

- Equilibrium exists between phosphorus in the solid phase and phosphorus in the soil solution.
- As plants absorb phosphorus, some of the bound phosphorus is released to restore balance.
- Soil pH and mineral content strongly influence phosphorus availability:
    - In acidic soils, phosphorus tends to bind with aluminum, iron, and manganese.
    - In alkaline soils, it forms compounds with calcium.
    - The optimal pH range for phosphorus availability is 6.0 to 7.0.
- Organic matter decomposition and crop residue breakdown contribute to the release of phosphorus into the soil solution.

6.4.4 Phosphorus Deficiency

- Signs of deficiency include:
    - Stunted plant growth
    - Dark purple coloration of older leaves
    - Poor flowering and weak root systems
- These symptoms typically appear when leaf phosphorus content falls below 0.2%.

6.4.5 Phosphorus Excess

- Over-application of phosphorus is common, particularly with compound NPK fertilizers or use of phosphoric acid in fertigation.
- Excess phosphorus can interfere with the uptake of micronutrients such as iron (Fe), manganese (Mn), and zinc (Zn), leading to secondary deficiencies.

6.5 Potassium (K)

6.5.1 Key Functions of Potassium in Plant Growth

- Enhance the quality of seeds and fruits
- Boosts resistance to diseases
- Plays a key role in carbohydrate metabolism, including the breakdown and movement of starches
- Supports the development of tubers and fruits
- Crucial for the synthesis of carbohydrates and proteins
- Promotes higher rates of photosynthesis
- Improves the efficiency of water use in plants
- Vital for proper fruit formation
- Activates enzymes and regulates the speed of their reactions

6.5.2 The Role of Potassium in Plant Growth and Development

Potassium is a vital macronutrient required in large quantities for the healthy growth and reproduction of plants. Often ranked second only to nitrogen in importance, potassium is widely referred to as the "quality nutrient" due to its significant impact on produce characteristics such as shape, size, color, and taste.

Plants absorb potassium in its ionic form (K^+), and this element plays a crucial role in several physiological processes:

- **Photosynthesis Regulation**: Potassium controls the opening and closing of stomata, directly influencing the uptake of carbon dioxide (CO_2).
- **Enzyme Activation**: It activates numerous enzymes and is essential for the production of Adenosine Triphosphate (ATP), a key energy source for various biochemical reactions in plant tissues.
- **Water Balance**: Potassium regulates both water uptake through the roots and water loss through stomata, contributing to improved drought resistance.
- **Protein Synthesis**: It is essential at nearly every step of protein formation.
- **Starch Formation**: The enzyme responsible for starch synthesis is activated by potassium. Through its diverse roles, potassium ensures that plants not only survive but thrive, resulting in higher quality and more resilient crops.
- **Enzyme Activation** – Potassium plays a crucial role in activating numerous enzymes that are essential for plant growth and development.

These enzymes regulate key physiological processes, including photosynthesis, protein synthesis, and energy metabolism.

6.5.3 Potassium Deficiency in Plants: Symptoms and Effects

Potassium deficiency can lead to a range of growth-related problems in plants. Since potassium is essential for various physiological functions, its absence affects overall plant health and productivity. Common signs and consequences of potassium deficiency include:

- **Chlorosis** One of the earliest symptoms, involves yellowing and scorching of leaf margins, typically starting from the middle and lower leaves.
- **Stunted Growth:** As potassium is a key catalyst for growth, deficient plants often exhibit slow or reduced growth.
- **Poor Tolerance to Stress:** Inadequate potassium impairs water regulation within the plant, making it more vulnerable to drought and extreme temperatures.
- **Defoliation:** If left untreated, potassium deficiency can lead to premature leaf drop. Leaves turn yellow, then brown, and eventually fall off, especially under stress conditions like heat or drought.

6.5.4 Other symptoms include:

- Increased susceptibility to pest attacks
- Weak and underdeveloped root systems
- Irregular or uneven ripening of fruits

6.5.5 Factors Influencing Potassium Uptake in Plants

Several environmental and soil-related factors affect the ability of plants to absorb potassium efficiently. Understanding these influences is crucial for optimizing nutrient management and plant health.

- **Oxygen Availability:** Adequate oxygen in the soil is essential for healthy root function, including the absorption of potassium. Poorly aerated soils can hinder nutrient uptake.
- **Soil Moisture** Higher moisture levels improve the movement of potassium ions in the soil, making it easier for plant roots to absorb them.
- **Soil Tillage** Regular tilling has been shown to enhance potassium availability by improving soil structure and root access.

- **Soil Temperature** The ideal temperature range for potassium uptake is between 60–80°F (15–27°C). Lower temperatures reduce root activity and slow down potassium absorption.

6.5.6 Forms of Potassium in Soil

1. **Fixed Potassium**
   This form of potassium is trapped between the layers of clay minerals and becomes slowly available over time. Wetting and drying cycles in the soil help release some of this potassium into the soil solution. Although essential, fixed potassium is not typically measured in standard soil tests due to its limited immediate availability.

2. **Exchangeable Potassium**
   This is the form most readily available to plants. It is loosely held on the surface of clay particles and organic matter and remains in equilibrium with the soil solution. As plants absorb potassium, more is released from these surfaces. Exchangeable potassium is measured in routine soil tests and is the primary source of potassium for plant uptake.

6.6. Importance of Manures

a) Enhances the organic matter content in the soil, improving overall soil health.
b) Supplies essential nutrients required for crop growth and development.
c) Helps bind soil particles together, improving soil structure.
d) Stimulates microbial activity, which supports nutrient cycling and soil fertility.
e) Boosts the biological functioning and regulation within the soil ecosystem.
f) Increases the organic carbon percentage, contributing to soil fertility and stability.
g) Improves the soil's water-holding capacity, aiding in drought resistance.
h) Enhances soil porosity, allowing better movement of air and water.
i) Promotes better aggregate stability, reducing soil compaction.
j) Improves soil aeration, supporting healthy root development.
k) Helps regulate soil temperature by buffering thermal fluctuations.
l) Reduces soil erosion by improving soil structure and stability.

6.7. Classification of Manures and Fertilizers

6.7.1 Manures:

Manure refers to well-decomposed organic waste from farm sources such as stubble, barnyard residues, animal excreta, and straw or other bedding materials. Manures are primarily used to enrich the soil with organic matter and essential nutrients.

(1) Organic Manures:

Organic manures are natural materials that improve soil fertility by supplying nutrients in small quantities and adding large amounts of organic matter. They are classified into two main types:

1. Bulky Organic Manures

These manures are applied in large quantities and are rich in organic matter but low in nutrient concentration. Common examples include:

- **Farmyard Manure (FYM)**
- **Compost**
- **Night Soil**
- **Sheep and Goat Manure**
- **Green Manure**

Each of these contributes to improved soil structure, moisture retention, and microbial activity.

Note: The nutrient content of bulky organic manures (on average) is:

- **Farmyard Manure:** N = 0.5%, P = 0.2%, K = 0.5%
- **Compost:** N = 0.5%, P = 0.15%, K = 0.5%
- **Sheep/Goat Manure:** N = 0.9%, P = 0.5%, K = 0.8%
- **Green Manure (e.g., Dhaincha):** N = 0.6% to 0.9%, with trace amounts of P and K

2. Concentrated Organic Manures

These are organic materials with higher nutrient content than bulky manures and are applied in smaller quantities. Examples include:

- **Oil Cakes** (e.g., neem, groundnut cake)
- **Blood Meal**

- **Fish Meal**
- **Bone Meal**

1) Manures of Plant Origin (Oil Cakes)

Oil cakes are the solid residues left after oil extraction from oilseeds. They are rich in nitrogen and are commonly used as organic manure. Oil cakes are broadly categorized into two types based on their edibility:

i) Non-Edible Oil Cakes

These oil cakes are not suitable for animal consumption and are used exclusively as manures. Examples include:

- Castor cake
- Cotton seed cake (undecorticated)
- Mahua cake
- Karanj (Pongamia) cake
- Neem cake
- Safflower cake (undecorticated)

ii) Edible Oil Cakes

These oil cakes can be used both as cattle feed and as manure. When used as manure, they contribute valuable nutrients to the soil. Examples include:

- Coconut cake
- Cottonseed cake (decorticated)
- Groundnut cake
- Linseed cake
- Niger cake
- Safflower cake (decorticated)
- Sesamum (til) cake
- Rape seed cake

(2) Manures of animal origin: Various types of animal origin manure are as under:

- **Blood Meal**
- **Fish Meal**
- **Bone Meal**

6.8 Green Manuring:

Green manuring refers to the agricultural practice of enhancing soil fertility and structure by incorporating fresh, undecomposed plant material, primarily leguminous plants, into the soil. This can involve either growing green plants directly in the field and ploughing them under or adding green leaves and plant matter from external sources to enrich the soil.

6.8.1 Green Manure Crop:

A green manure crop is grown specifically to enhance soil fertility by increasing its organic matter content. These crops are usually incorporated into the soil before they mature, helping to improve soil structure, nutrient availability, and overall soil health.

6.8.2 Types of Green Manuring

1. **Green Manuring in Situ**
   In this method, green manure crops are grown directly in the field and then ploughed into the same soil before they mature. Common green manure crops include Sunhemp, Dhaincha, Cowpea, Matki, Mung, Udid, Kulthi, and Guar. These crops help improve soil fertility and organic matter content.

2. **Green Leaf Manuring**
   This involves collecting tender green leaves and branches from nearby wastelands, forests, or trees grown on bunds (field edges). These green materials are spread over the field and incorporated into the soil to enrich it. Common sources include shrubs and trees, whose leaves and twigs are cut and turned into the soil.

6.8.3 Advantages of Green Manuring

1. **Enhances Organic Matter**
   Green manuring adds organic matter to the soil, which stimulates the activity of beneficial soil microorganisms.

2. **Improves Soil Structure**
   It enhances soil texture and structure, increasing water-holding capacity while reducing surface runoff and erosion caused by rainfall.

3. **Fixes Atmospheric Nitrogen**
   Leguminous green manure crops fix nitrogen from the atmosphere, enriching the soil with this essential nutrient.

4. **Boosts Nutrient Availability**
   It increases the availability of key nutrients such as phosphorus, potassium, calcium, magnesium, and iron.

5. **Suppresses Weed Growth**
   The dense growth of green manure crops helps smother and suppress the growth of unwanted weeds.

6. **Recycles Deep Soil Nutrients**
   These crops extract nutrients from deeper soil layers and bring them to the upper layers where they are more accessible to subsequent crops.

6.8.4 Disadvantages of Green Manuring

1. **Increased Risk of Pests and Diseases**
   Green manure crops may harbor pests and diseases, potentially affecting subsequent crops.

2. **Loss of a Growing Season**
   Using land for green manure crops may result in the loss of a food or cash crop during that season.

3. **Moisture Depletion**
   Green manure crops can reduce soil moisture, which may negatively impact the growth of the next crop, especially in areas with limited rainfall.

4. **Higher Costs**
   The cost of cultivating green manure crops, including seeds, labor, and field preparation, can sometimes exceed the cost of applying commercial nitrogen fertilizers.

6.9 Characters of a Good Green Manuring Crop

1. It should yield a large quantity of green material in a short period.
2. It should be quick-growing, especially in the beginning, to suppress the weeds.
3. It should preferably be a legume.
4. It should be succulent and have more leafy growth.

5. It should have deep and fibrous root system.

6. It should be able to grow even or poor soils.

6.10. Self-Assessment Questions

carbon dioxide is absorbed through ____ part of the plant

_____nutrient enhances the quality of fruits

_____ nutrient play a key role in the photosynthesis process

Production of dry matter by using sunlight is called _____.

_____ nutrient is responsible for root growth of plant

Answers

1) Leaves 2) Potassium 3) Nitrogen 4) Photosynthesis 5) Phosphorus

6.11 Refrence

1. Archer, J. (1985). Crop nutrition and fertiliser use (pp. 258-pp).
2. Chen, Q., Song, Y., An, Y., Lu, Y., & Zhong, G. (2024). Soil microorganisms: Their role in enhancing crop nutrition and health. *Diversity*, *16*(12), 734.
3. Magen, H. (2008). Balanced crop nutrition: fertilizing for crop and food quality. Turkish Journal of Agriculture and Forestry, 32(3), 183-193.
4. Kirkby, E. A., & Johnston, A. E. (2008). Soil and fertilizer phosphorus in relation to crop nutrition. *The ecophysiology of plant-phosphorus interactions*, 177-223.
5. Rengel, Z. (2024). *Mineral nutrition of crops: Fundamental mechanisms and implications*. CRC Press.
6. Robert, P. C. (2002). Precision agriculture: a challenge for crop nutrition management. Plant and soil, 247(1), 143-149.
7. Römheld, V., & Kirkby, E. A. (2007). *Magnesium functions in crop nutrition and yield* (No. 616, pp. 1-22).
8. Torres-Olivar, V., Villegas-Torres, O. G., Domínguez-Patiño, M. L., Sotelo-Nava, H., Rodríguez-Martínez, A., Melgoza-Alemán, R. M., ... & Alia-Tejacal, I. (2014). Role of nitrogen and nutrients in crop nutrition. *Journal of Agricultural Science and Technology. B*, *4*(1B), 29.

Unit: 7

AGRO-ECOLOGICAL ZONES OF PAKISTAN

Compiled by: Dr. Muhammad Rehan
Reviewed by: Dr. Sabir Hussain Shah
Muhammad Fahd Bhatti

CONTENTS

Introduction :..... 91
Objectives : 91
Learning outcomes:..... 91
7.1 Introduction to Agro-Ecological Zones 92
7.2 Indus Delta..... 92
7.3 Southern Irrigated Plain..... 93
7.4 Sandy Desert (Thar Desert) 95
7.5 Northern Irrigated Plain..... 96
7.6 Barani (Rainfall) Zone..... 97
7.7 Wet Mountains..... 98
7.8 Northern Dry Mountains..... 100
7.9 Western Dry Mountains..... 102
7.10. Dry Western Plateau 104
7.11 Sulaiman Piedmont..... 106
7.12 Conclusion and Comparative Analysis..... 108
7.13 Self-Assessment Questions..... 112
7.14 References..... 112

INTRODUCTION :

Pakistan has a diverse geography and climate, which makes its agriculture unique and varied. Different areas of the country have distinct soils, rainfall patterns, temperatures, and cropping systems. To better understand and utilize these differences, Pakistan is divided into agro-ecological zones. Each zone has its own potential for certain crops, fruits, vegetables, and livestock production.

Studying agro-ecological zones helps in identifying the suitable crops and farming practices for each region, ensuring efficient use of natural resources. It also assists in tackling challenges like low productivity, water scarcity, and climate change by promoting region-specific solutions. This knowledge is essential for sustainable agricultural planning and food security in Pakistan.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the concept of agro-ecological zones and their importance in agriculture.
2. Identify the major agro-ecological zones of Pakistan and their characteristics, such as soil, climate, and topography.
3. Describe the crops, fruits, vegetables, and livestock best suited to each zone.
4. Highlight the role of agro-ecological zoning in improving agricultural productivity and resource management.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. **Define and explain** the concept of agro-ecological zones.
2. **Identify and locate** the major agro-ecological zones of Pakistan on a map.
3. **Describe** the climatic conditions, soil types, and topographical features of each zone.
4. **Match** suitable crops, fruits, vegetables, and livestock with the zones where they can best be cultivated.
5. **Analyze** how agro-ecological zoning supports resource management, crop planning, and agricultural policies.

7.1 Introduction to Agro-Ecological Zones

Definition and Concept

Agro-ecological zones (AEZs) are geographical areas with similar climatic conditions, soil types, landforms, and water resources that determine their agricultural potential and production systems. Pakistan, with its diverse topography ranging from coastal plains to high mountain ranges, encompasses ten distinct agro-ecological zones, each with unique characteristics that influence agricultural practices, crop selection, and farming systems.

Importance of AEZ Classification

The classification of Pakistan into agro-ecological zones serves several crucial purposes:

- **Agricultural Planning**: Helps in formulating region-specific agricultural policies and development strategies
- **Crop Zonation**: Assists in identifying suitable crops for different regions based on climatic and soil conditions
- **Resource Management**: Enables efficient utilization of water, soil, and other natural resources
- **Risk Assessment**: Helps in understanding climate-related risks and vulnerabilities in different regions
- **Technology Transfer**: Facilitates the adoption of appropriate agricultural technologies for specific zones

7.2 Indus Delta

Geographic Location and Extent

The Indus Delta, also known as the Indus River Delta, is located in the southern part of Sindh province, covering an area of approximately 41,440 square kilometers. This zone extends from Kotri Barrage to the Arabian Sea, encompassing the coastal districts of Thatta, Badin, and parts of Hyderabad and Karachi.

Topography and Landforms

The Indus Delta is characterized by **Flat Alluvial Plains** Formed by centuries of sediment deposition from the Indus River, **Active and Abandoned Channels,** a network of distributaries and old river channels, **Coastal Areas** Including beaches, mudflats, and mangrove forests, **Islands and Creeks** Numerous small islands formed by river sediments, and low elevation Most areas lie below 100 meters above sea level

Climate

The climate of the Indus Delta is:

- **Arid to Semi-arid**: With hot, dry summers and mild winters
- **Temperature**: Summer temperatures range from 35-45°C, winter temperatures from 10-25°C
- **Rainfall**: Annual precipitation ranges from 125-250mm, mostly during the monsoon season
- **Humidity**: High humidity due to proximity to the Arabian Sea
- **Winds**: Influenced by sea breezes and monsoon winds

Soil Characteristics

Predominantly alluvial soils with varying textures, generally fertile but affected by salinity in coastal areas. Poor drainage in many areas, leading to waterlogging**.** High soil salinity due to seawater intrusion and poor drainage. Low to moderate organic matter content is present.

Water Resource:

Primarily depends on the Indus River water through canals**,** Brackish to saline groundwater, limiting its agricultural use. Inadequate and erratic rainfall make irrigation essential**. Sea water is** a major Problem as well Affecting Groundwater Quality

Agricultural Characteristics

Major Crops:

Rice: The dominant kharif crop, well-adapted to the deltaic conditions, **Wheat**: Important rabi crop, though yields are affected by salinity, **Cotton**: Grown in less saline areas, **Sugarcane**: Limited cultivation in suitable regions, **Vegetables**: Various vegetables, including onions, tomatoes, and leafy greens

Farming Systems:

The Indus Delta has four major farming systems: the Rice-Wheat System, Mixed Farming, Aquaculture, and the Horticultural System.

7.3 Southern Irrigated Plain

Geographic Location and Extent

The Southern Irrigated Plain covers the central and southern parts of Sindh and southern Punjab, extending over approximately 78,000 square kilometers. This

zone includes districts such as Sukkur, Larkana, Nawabshah, Hyderabad (northern parts), Multan, Bahawalpur, and adjacent areas.

Topography and Landforms

It includes Flat to Gently Undulating Plains Formed by the Indus River alluvium **And River Terraces** Old and new alluvial terraces along the Indus. **Doabs** are interfluves between rivers and canals. **Elevation** generally ranges from 50 to 200 meters above sea level. **Slope** Very gentle slope towards the south

Climate

- **Arid to Semi-arid**: Hot, dry climate with extreme temperatures
- **Temperature**: Summer temperatures can exceed 48°C, winter ranges from 5-20°C
- **Rainfall**: Annual precipitation 100-400mm, concentrated in monsoon months
- **Evaporation**: High evaporation rates due to intense heat and low humidity
- **Dust Storms**: Common during the pre-monsoon period

Soil Characteristics

- **Soil Type**: Deep, fertile alluvial soils
- **Texture**: Predominantly silty clay to clay loam
- **Fertility**: High natural fertility with good nutrient content
- **Structure**: Well-developed structure in upper horizons
- **Limitations**: Salinity and alkalinity problems in some areas

Water Resources

- **Canal Irrigation**: An Extensive network of canals from the Indus River system
- **Groundwater**: Generally good quality groundwater available
- **Tube Wells**: Widely used for supplementary irrigation
- **Water Management**: Well-developed irrigation infrastructure
- **Drainage**: Some areas face drainage problems

7.4 Sandy Desert (Thar Desert)

Geographic Location and Extent

The Sandy Desert zone, primarily comprising the Thar Desert, covers southeastern Sindh and extends into Rajasthan, India. In Pakistan, it covers approximately 175,000 square kilometers, including districts like Tharparkar, Umerkot, Mirpur Khas (eastern parts), and Sanghar (eastern parts).

Topography and Landforms

- **Sand Dunes**: Extensive mobile and semi-mobile sand dune systems
- **Desert Plains**: Flat to undulating sandy plains between dunes
- **Rocky Outcrops**: Isolated hills and rocky formations
- **Playas**: Temporary salt lakes in depression areas
- **Elevation**: Ranges from 100-300 meters above sea level

Climate

- **Arid Desert Climate**: Extremely hot and dry conditions
- **Temperature**: Summer temperatures often exceed 50°C, winter 5-25°C
- **Rainfall**: Very low annual precipitation (100-250mm)
- **Seasonality**: Most rainfall occurs during monsoon months (July-September)
- **Wind**: Strong winds are causing sand movement and dust storms
- **Solar Radiation**: High solar intensity throughout the year

Soil Characteristics

- **Soil Type**: Sandy soils with low water retention
- **Texture**: Predominantly sandy with low clay content
- **Fertility**: Generally low fertility due to low organic matter
- **pH**: Neutral to slightly alkaline
- **Depth**: Variable soil depth over rocky substrate

Water Resources

- **Rainfall Dependent**: Primarily depends on erratic rainfall
- **Groundwater**: Limited and often brackish
- **Surface Water**: Ephemeral streams during the rainy season

- **Water Harvesting**: Traditional water conservation methods
- **Wells**: Shallow wells and ponds for water storage

Natural Vegetation and Livestock

Vegetation:

- **Sparse Desert Vegetation**: Thorny shrubs and drought-resistant plants
- **Grass Species**: Various drought-tolerant grasses
- **Trees**: Khejri, Babul, and other desert-adapted species

7.5 Northern Irrigated Plain

Geographic Location and Extent

The Northern Irrigated Plain encompasses the central and northern parts of Punjab province, covering approximately 63,000 square kilometers. This zone includes major districts such as Lahore, Faisalabad, Multan (northern parts), Sahiwal, Okara, Pakpattan, Jhang, Toba Tek Singh, and surrounding areas.

Topography and Landforms

- **Alluvial Plains**: Flat to gently sloping plains formed by river deposits
- **River Valleys**: Valleys of the Ravi, Chenab, and Sutlej rivers
- **Doabs**: Fertile interfluves between major rivers
- **Elevation**: Generally ranges from 150-300 meters above sea level
- **Slope**: Gentle slope from northeast to southwest

Climate

- **Semi-arid to Sub-humid**: Transitional climate zone
- **Temperature**: Summer maximum 40-45°C, winter minimum 2-8°C
- **Rainfall**: Annual precipitation 250-500mm
- **Seasonality**: Monsoon rains (July-September) and winter rains
- **Weather Patterns**: Distinct hot summer, mild winter, and monsoon seasons

Soil Characteristics

- **Soil Type**: Deep alluvial soils of high fertility
- **Texture**: Silty clay loam to clay loam
- **Fertility**: Very high natural fertility

- **Organic Matter**: Moderate to good organic matter content
- **Structure**: Well-developed soil structure
- **Drainage**: Generally well-drained soils

Water Resources

- **Canal System**: Extensive irrigation network from the Indus River system
- **Major Barrages**: Tarbela, Mangla, and other barrages
- **Groundwater**: High-quality groundwater resources
- **Tube Wells**: Widely used for irrigation
- **Water Table**: Generally favorable water table conditions

7.6 Barani (Rainfall) Zone

Geographic Location and Extent

The Barani zone extends across the Pothohar Plateau in northern Punjab and parts of Khyber Pakhtunkhwa, covering approximately 22,000 square kilometers. This zone includes districts such as Rawalpindi, Attock, Jhelum, Chakwal, parts of Mianwali, and surrounding areas that depend primarily on rainfall for agriculture.

Topography and Landforms

- **Undulating Plateau**: Rolling hills and dissected plateau terrain
- **Valley Systems**: Narrow valleys between ridges and hills
- **Erosional Features**: Gullies and ravines due to water erosion
- **Elevation**: Ranges from 300-800 meters above sea level
- **Slope**: Moderate to steep slopes affecting agriculture

Climate

- **Sub-humid to Semi-arid**: Transitional climate with seasonal variations
- **Temperature**: Summer maximum 35-42°C, winter minimum 0-5°C
- **Rainfall**: Annual precipitation 400-800mm
- **Rainfall Pattern**: Bimodal distribution with monsoon and winter rains
- **Variability**: High inter-annual rainfall variability
- **Growing Season**: Limited by water availability

Soil Characteristics

- **Soil Type**: Shallow to moderately deep soils

- **Parent Material**: Derived from sandstone and clay formations
- **Texture**: Sandy loam to clay loam
- **Fertility**: Moderate fertility with nutrient limitations
- **Erosion**: Susceptible to water and wind erosion
- **Organic Matter**: Low to moderate organic matter content

Water Resources

- **Rainfall Dependent**: Primarily depends on seasonal rainfall
- **Groundwater**: Limited and often deep groundwater
- **Surface Storage**: Ponds and small reservoirs for water harvesting
- **Seasonal Streams**: Ephemeral streams during rainy seasons
- **Water Conservation**: Traditional water conservation practices

Livestock Systems

- **Cattle and Buffalo**: Indigenous breeds adapted to local conditions
- **Small Ruminants**: Goats and sheep are well-suited to rangeland
- **Poultry**: Backyard poultry keeping
- **Feed Resources**: Crop residues and natural vegetation
- **Integration**: Crop-livestock integration for better resource use

Environmental Aspects

- **Natural Vegetation**: Mixed scrub and grassland vegetation
- **Biodiversity**: Habitat for various flora and fauna species
- **Watershed Functions**: Important for water recharge and conservation
- **Carbon Sequestration**: Potential for carbon storage in soils and vegetation
- **Ecosystem Services**: Various environmental services are provided

7.7 Wet Mountains

Geographic Location and Extent

The Wet Mountains zone encompasses the humid and sub-humid mountainous regions of northern Pakistan, including parts of Khyber Pakhtunkhwa, northern Punjab (Murree hills), and Azad Kashmir. This zone covers approximately 15,000

square kilometers and includes areas receiving substantial precipitation from both monsoon and western disturbances.

Topography and Landforms

- **Mountainous Terrain**: Steep slopes and deep valleys
- **Elevation Range**: 1,000-4,000 meters above sea level
- **Valley Systems**: Narrow valleys with steep sides
- **Terraced Slopes**: Agricultural terraces on mountain slopes
- **River Gorges**: Deep gorges carved by mountain streams
- **Landslide Areas**: Zones prone to landslides during heavy rains

Climate

- **Humid to Sub-humid**: High moisture conditions
- **Temperature**: Varies with altitude, cooler than the plains
- **Rainfall**: High annual precipitation (800-1,500mm or more)
- **Seasonality**: Monsoon rains and winter precipitation
- **Snow**: Snowfall at higher elevations during winter
- **Growing Season**: Extended growing season due to moisture availability

Soil Characteristics

- **Soil Type**: Mountain soils with varying depths
- **Parent Material**: Derived from various geological formations
- **Texture**: Variable from sandy loam to clay loam
- **Fertility**: Generally fertile due to organic matter accumulation
- **Drainage**: Well-drained on slopes, some poorly drained in valleys
- **Erosion Risk**: High erosion potential on steep slopes

Water Resources

- **Abundant Rainfall**: Reliable precipitation throughout the year
- **Springs**: Numerous natural springs and streams
- **River Systems**: Permanent rivers and tributaries
- **Groundwater**: Good groundwater recharge due to high precipitation
- **Seasonal Variation**: Some seasonal variation in water availability

Forest Resources

- **Natural Forests**: Coniferous and deciduous forest types
- **Species Diversity**: Rich biodiversity of tree species
- **Timber Production**: Commercial timber harvesting
- **Non-Timber Products**: Mushrooms, medicinal plants, and other products
- **Conservation**: Need for sustainable forest management

Livestock Systems

- **Mountain Breeds**: Indigenous breeds adapted to mountain conditions
- **Transhumance**: Seasonal movement of livestock to pastures
- **Dairy Production**: Milk production from cattle and buffalo
- **Small Ruminants**: Goats and sheep are well-adapted to mountains
- **Yaks**: At very high elevations in northern areas

Environmental Significance

- **Watershed Protection**: Important for downstream water security
- **Biodiversity Conservation**: Rich biodiversity requires conservation
- **Carbon Sequestration**: Forest and agricultural systems storing carbon
- **Ecosystem Services**: Various environmental services are provided
- **Climate Regulation**: Role in local and regional climate regulation

7.8 Northern Dry Mountains

Geographic Location and Extent

The Northern Dry Mountains zone covers the arid and semi-arid mountainous regions of northern Pakistan, including parts of Gilgit-Baltistan, upper Khyber Pakhtunkhwa, and northern tribal areas. This zone encompasses approximately 72,000 square kilometers of high-altitude desert and semi-desert terrain.

Topography and Landforms

- **High Mountain Ranges**: Including Hindu Kush, Karakoram, and the western Himalayas
- **Elevation**: Ranges from 1,500 to over 8,000 meters above sea level
- **Arid Valleys**: Deep, narrow valleys with steep sides
- **Glacial Features**: Glaciers, moraines, and glacial valleys

- **Desert Plateaus**: High-altitude desert and semi-desert areas
- **Rocky Terrain**: Exposed rock faces and scree slopes

Climate

- **Cold Arid Climate**: High altitude with low precipitation
- **Temperature**: Extreme temperature variations, very cold winters
- **Precipitation**: Low annual precipitation (100-400mm)
- **Seasonality**: Limited growing season due to cold temperatures
- **Solar Radiation**: High solar intensity due to altitude and clear skies
- **Wind**: Strong winds in exposed areas

Soil Characteristics

- **Soil Type**: Shallow, stony mountain soils
- **Parent Material**: Derived from various rock types
- **Texture**: Sandy loam to loamy sand with high stone content
- **Fertility**: Generally low fertility due to harsh conditions
- **Organic Matter**: Very low organic matter content
- **Development**: Poorly developed soils due to extreme climate

Water Resources

- **Limited Precipitation**: Very low and erratic rainfall
- **Glacial Melt**: Water from glacial and snow melt
- **Springs**: Limited spring water sources
- **Rivers**: Seasonal and ephemeral water courses
- **Irrigation**: Traditional irrigation systems where water is available
- **Water Scarcity**: Severe water limitations for agriculture

Livestock Systems

Traditional Pastoralism:

- **Yaks**: At very high elevations
- **Goats**: Hardy breeds adapted to mountain conditions
- **Sheep**: Mountain breeds with good cold tolerance
- **Cattle**: Limited numbers in suitable areas

- **Camels**: In some lower-elevation arid areas

Management Systems:

- **Transhumance**: Seasonal movement to different grazing areas
- **Extensive Grazing**: Large areas needed per animal
- **Feed Scarcity**: Limited feed resources during winter
- **Hardy Breeds**: Use of indigenous breeds adapted to harsh conditions

Challenges and Constraints

- **Harsh Climate**: Extreme cold and short growing seasons
- **Water Scarcity**: Limited and unreliable water resources
- **Remote Location**: Isolated areas with poor connectivity
- **Market Access**: Difficulty in reaching markets
- **Input Supply**: Limited access to agricultural inputs
- **Technology**: Inappropriate technologies for mountain conditions

Adaptation Strategies

- **Climate-Resilient Crops**: Use of hardy, adapted varieties
- **Water Harvesting**: Collection and storage of scarce water
- **Greenhouse Production**: Protected cultivation systems
- **Diversification**: Multiple income sources for risk reduction
- **Traditional Knowledge**: Preservation and use of indigenous knowledge

Environmental Significance

- **Biodiversity**: Unique high-altitude ecosystems
- **Watershed**: Important for downstream water resources
- **Climate Change**: Vulnerable to climate change impacts
- **Conservation**: Need for conservation of fragile ecosystems
- **Carbon Storage**: Limited but important carbon sequestration

7.9 Western Dry Mountains

Geographic Location and Extent

The Western Dry Mountains zone encompasses the arid mountainous regions along Pakistan's western border, including parts of Balochistan and western

Khyber Pakhtunkhwa. This zone covers approximately 90,000 square kilometers and includes districts such as Quetta, Pishin, Zhob, Waziristan, and adjacent mountainous areas.

Topography and Landforms

- **Mountain Ranges**: Sulaiman Range, Toba Kakar Range, and other western ranges
- **Elevation**: Ranges from 1,000-3,500 meters above sea level
- **Arid Valleys**: Intermontane valleys with limited water resources
- **Plateaus**: High-altitude plateaus and mesas
- **Escarpments**: Steep mountain faces and cliffs
- **Pediments**: Gently sloping surfaces at mountain bases

Climate

- **Arid Continental**: Hot summers, cold winters, low precipitation
- **Temperature**: Wide diurnal and seasonal temperature variations
- **Precipitation**: Very low annual rainfall (100-300mm)
- **Seasonality**: Winter precipitation from western disturbances
- **Drought**: Frequent drought conditions
- **Wind**: Strong winds are causing dust storms

Soil Characteristics

- **Soil Type**: Shallow, rocky mountain soils
- **Parent Material**: Derived from limestone, sandstone, and shale
- **Texture**: Sandy loam to clay loam with high gravel content
- **Fertility**: Low to moderate fertility
- **Erosion**: High erosion potential due to sparse vegetation
- **Organic Matter**: Very low organic matter content

Water Resources

- **Limited Rainfall**: Extremely low and erratic precipitation
- **Seasonal Streams**: Ephemeral water courses during rainy periods
- **Springs**: Limited spring water in some areas

- **Groundwater**: Deep and often brackish groundwater
- **Karez Systems**: Traditional underground irrigation channels
- **Water Harvesting**: Traditional methods for water collection and storage

Traditional Practices

- **Water Management**: Sophisticated traditional irrigation systems
- **Crop Selection**: Use of drought and cold-tolerant varieties
- **Soil Conservation**: Traditional terracing and conservation methods
- **Seasonal Timing**: Precise timing of agricultural activities
- **Risk Management**: Diversified cropping and livelihood strategies

Livestock Systems

Animal Types:

- **Goats**: Predominant livestock, well-adapted to mountains
- **Sheep**: Hardy breeds suitable for rangeland grazing
- **Cattle**: Limited numbers in areas with adequate feed
- **Camels**: In lower-elevation desert areas
- **Poultry**: Backyard poultry keeping for eggs and meat

Grazing Systems:

- **Extensive Grazing**: Large areas required per animal unit
- **Seasonal Movement**: Migration to different grazing areas
- **Rangeland Management**: Traditional grazing management practices
- **Feed Scarcity**: Limited feed availability, especially in winter
- **Integration**: Crop-livestock integration where possible

7.10. Dry Western Plateau

Geographic Location and Extent

The Dry Western Plateau encompasses the elevated plateau regions of central and southern Balochistan, covering approximately 134,000 square kilometers. This zone includes districts such as Kalat, Mastung, Nushki, Chagai, Kharan, and surrounding plateau areas characterized by extreme aridity and harsh climatic conditions.

Topography and Landforms

- **High Plateaus**: Elevated flat-topped landforms
- **Elevation**: Ranges from 1,000-2,500 meters above sea level
- **Intermontane Basins**: Closed basins between mountain ranges
- **Playas**: Seasonal salt lakes and dry lake beds
- **Pediplains**: Gently sloping erosional surfaces
- **Isolated Hills**: Scattered rocky hills and mesas

Climate

- **Hyperarid to Arid**: Extremely dry desert climate
- **Temperature**: Extreme temperature variations, very hot summers, cold winters
- **Precipitation**: Very low annual rainfall (50-200mm)
- **Evaporation**: Extremely high evaporation rates
- **Dust Storms**: Frequent dust storms and strong winds
- **Drought**: Chronic water scarcity conditions

Soil Characteristics

- **Soil Type**: Shallow, poorly developed desert soils
- **Parent Material**: Mixed alluvial and colluvial materials
- **Texture**: Sandy to sandy loam with high gravel content
- **Salinity**: High salt content in many areas
- **Fertility**: Very low fertility and organic matter
- **Crusting**: Surface crusting limits water infiltration

Water Resources

- **Extremely Limited**: Severe water scarcity throughout the zone
- **Groundwater**: Deep, often saline groundwater
- **Rainfall**: Inadequate and highly erratic precipitation
- **Surface Water**: Rare and ephemeral surface water sources
- **Traditional Systems**: Ancient water harvesting and conservation methods

Pastoral Systems

Livestock Types:

- **Goats**: Predominant livestock species
- **Sheep**: Desert-adapted breeds
- **Camels**: Well-suited to desert conditions
- **Cattle**: Very limited numbers

Management:

- **Extensive Systems**: Very large areas per animal
- **Nomadic Patterns**: Seasonal movement following water and pasture
- **Survival Strategies**: Adaptation to extreme resource scarcity
- **Traditional Knowledge**: Indigenous pastoral management systems

Natural Resources

Mineral Resources:

- **Coal**: Significant coal deposits
- **Natural Gas**: Natural gas reserves
- **Metallic Minerals**: Various metallic ore deposits
- **Non-metallic Minerals**: Salt, gypsum, and other minerals

Energy Potential:

- **Solar Energy**: Excellent solar radiation for power generation
- **Wind Energy**: Good wind resources in many areas
- **Geothermal**: Potential geothermal energy sources

7.11 Sulaiman Piedmont

Geographic Location and Extent

The Sulaiman Piedmont zone lies along the eastern foothills of the Sulaiman Range, covering approximately 12,000 square kilometers. This zone includes parts of districts such as D.G. Khan, Rajanpur, Muzaffargarh (western parts), and adjacent areas in southern Punjab and eastern Balochistan.

Topography and Landforms

- **Piedmont Plains**: Gently sloping plains at the base of mountains
- **Alluvial Fans**: Cone-shaped deposits from mountain streams
- **Badlands**: Eroded terrain with gullies and ravines

- **Terraces**: River and stream terraces
- **Elevation**: Ranges from 100-500 meters above sea level
- **Slope**: Moderate slopes from mountains toward plains

Climate

- **Arid to Semi-arid**: Hot, dry climate with low precipitation
- **Temperature**: Extreme summer heat (up to 50°C), mild winters
- **Rainfall**: Low annual precipitation (150-400mm)
- **Seasonality**: Monsoon and winter precipitation
- **Dust Storms**: Frequent during the pre-monsoon period
- **Evaporation**: High evaporation rates due to heat and low humidity

Soil Characteristics

- **Soil Type**: Mixed alluvial and colluvial soils
- **Texture**: Sandy loam to loamy sand
- **Fertility**: Low to moderate fertility
- **Depth**: Variable depth over rocky substrate
- **Erosion**: Susceptible to water and wind erosion
- **Salinity**: Some areas are affected by salinity

Water Resources

- **Seasonal Streams**: Torrential streams from the mountains during the rains
- **Groundwater**: Limited and often brackish
- **Canal Water**: Limited canal irrigation from the Indus system
- **Tube Wells**: Some tube well irrigation
- **Flash Floods**: Sudden floods from mountain catchments
- **Water Harvesting**: Traditional and modern water conservation

Water Management

- **Flood Irrigation**: Traditional flood irrigation from seasonal streams
- **Check Dams**: Small dams to control water flow
- **Water Channels**: Distribution channels for irrigation water
- **Groundwater Development**: Tube wells where aquifers are available

- **Soil and Water Conservation**: Measures to prevent erosion

Livestock Systems

- **Cattle and Buffalo**: Important for dairy and draft power
- **Small Ruminants**: Goats and sheep adapted to local conditions
- **Extensive Grazing**: Use of rangelands and crop residues
- **Stall Feeding**: Supplementary feeding during scarcity periods
- **Traditional Breeds**: Indigenous breeds adapted to the local climate

Natural Vegetation

- **Desert Scrub**: Sparse desert vegetation
- **Riverine Forests**: Along seasonal streams
- **Grasslands**: Limited grassland areas
- **Thorny Species**: Drought-adapted thorny shrubs and trees
- **Medicinal Plants**: Various medicinal plant species

Environmental Considerations

- **Desertification**: Risk of land degradation
- **Biodiversity**: Unique desert and semi-desert ecosystems
- **Climate Change**: Vulnerability to climate change impacts
- **Conservation**: Need for sustainable resource management
- **Watershed Management**: Important for downstream areas

7.12 Conclusion and Comparative Analysis

Summary of Agro-Ecological Zones

Pakistan's ten agro-ecological zones represent a remarkable diversity of climatic, edaphic, and topographic conditions that significantly influence agricultural practices, crop selection, and farming systems across the country. From the coastal deltaic environment of the Indus Delta to the high-altitude deserts of the Northern Dry Mountains, each zone presents unique opportunities and challenges for agricultural development.

Comparative Productivity and Potential

High Productivity Zones:

- **Northern Irrigated Plain**: Highest agricultural productivity with intensive farming systems

- **Southern Irrigated Plain**: Major contributor to cotton and wheat production
- **Indus Delta**: Important for rice production despite salinity challenges

Medium Productivity Zones:

- **Barani Zone**: Moderate productivity dependent on rainfall patterns
- **Wet Mountains**: Good potential for high-value crops and horticulture
- **Sulaiman Piedmont**: Variable productivity based on water availability

Low Productivity Zones:

- **Sandy Desert**: Limited agriculture, primarily pastoral systems
- **Northern Dry Mountains**: Harsh conditions limit agricultural potential
- **Western Dry Mountains**: Specialized crops adapted to arid conditions
- **Dry Western Plateau**: Minimal agriculture due to extreme aridity

Water Resource Utilization

The distribution and utilization of water resources across these zones highlight the critical importance of water management in Pakistani agriculture:

1. **Canal Irrigated Zones** (Northern and Southern Irrigated Plains): Benefit from extensive canal networks from the Indus River system
2. **Rainfall Dependent Zones** (Barani and Wet Mountains): Rely on seasonal precipitation with varying reliability
3. **Water Scarce Zones** (Desert areas and dry mountains): Face severe water constraints requiring specialized management approaches

Climate Change Implications

Each agro-ecological zone faces different climate change challenges:

- **Temperature Increases**: All zones are experiencing rising temperatures
- **Precipitation Changes**: Altered rainfall patterns affecting rainfed areas
- **Extreme Events**: Increased frequency of droughts, floods, and storms
- **Water Availability**: Changing water resources affecting irrigated zones
- **Crop Suitability**: Shifting crop zones and varieties

Development Priorities

Zone-Specific Priorities:

1. **Irrigated Plains**: Water use efficiency, soil health, and sustainable intensification
2. **Rainfed Areas**: Drought resilience, soil conservation, and crop diversification
3. **Mountain Zones**: Terracing, horticulture development, and value chain improvement
4. **Arid Zones**: Water harvesting, drought-adapted crops, and livestock improvement

Technology Adoption Patterns

Technology adoption varies significantly across zones:

- **High-Input Zones**: Advanced machinery, improved varieties, and precision agriculture
- **Resource-Limited Zones**: Appropriate technology, water-efficient systems, and indigenous practices
- **Remote Areas**: Traditional methods with gradual introduction of suitable innovations

Market Integration and Value Chains

Market access and integration differ across zones:

- **Well-Connected Zones**: Direct access to national and international markets
- **Remote Zones**: Limited market access requiring value addition and processing
- **Specialized Production**: Focus on niche markets and high-value products

Sustainability Challenges

Common sustainability challenges across zones include:

- **Resource Degradation**: Soil erosion, salinity, and fertility decline
- **Water Management**: Efficient use and conservation of water resources
- **Biodiversity Loss**: Reduction in crop and natural biodiversity
- **Climate Adaptation**: Building resilience to climate change impacts

Future Directions

Research and Development:

- Zone-specific crop varieties and farming systems
- Water-efficient technologies and practices
- Climate-resilient agricultural systems
- Integrated pest and nutrient management

Policy Interventions:

- Differential support based on zone characteristics
- Investment in infrastructure and market access
- Capacity building and extension services
- Environmental protection and restoration

Institutional Support:

- Strengthening local institutions and farmer organizations
- Improving credit and insurance systems
- Enhancing research-extension-farmer linkages
- Promoting public-private partnerships

Conclusion

The agro-ecological zone classification provides a valuable framework for understanding Pakistan's agricultural diversity and developing targeted interventions for sustainable agricultural development. Success in improving agricultural productivity and sustainability will depend on recognizing and working with the natural characteristics of each zone while building resilience to climate change and market volatility.

The diversity of Pakistan's agro-ecological zones is both a challenge and an opportunity. It requires differentiated approaches to agricultural development but also provides multiple options for crop production, risk distribution, and adaptation to changing conditions. By understanding and leveraging the unique characteristics of each zone, Pakistan can work toward a more sustainable, productive, and resilient agricultural system that serves the needs of its diverse population while protecting its valuable natural resources.

Effective management of these diverse agroecological zones will be crucial for Pakistan's food security, rural livelihoods, and economic development in the decades to come. The integration of traditional knowledge with modern

technologies, coupled with appropriate policy support and institutional frameworks, will determine the success of agricultural development efforts across these varied landscapes.

7.13 Self-Assessment Questions

Fill the blanks

1. Elevation, slope, and landforms come under _____category.
2. Growing of crops in proper sequence is termed as _____
3. Relative proportion of sand, silt and clay particles of soil is known as _____.
4. _____is a type of farming without irrigation.
5. There are _____ agroecological zones of Pakistan

Answers

1) Topography 2) Crop rotation 3) Soil texture 4) Dryland farming 5) Ten

7.14 References

1. FAO, IIASA, ISRIC, ISSCAS, & JRC. (2012). *Harmonized world soil database* (Version 1.2). FAO & IIASA.
2. Food and Agriculture Organization of the United Nations. (2018). *Pakistan: Country profile – Food and agriculture*. FAO.
3. Panel on Climate Change. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects*. Cambridge University Press.
4. International Rice Research Institute. (2019). *Rice production in saline soils: Management strategies*. IRRI.
5. Ministry of Climate Change. (2012). *National climate change policy*. Government of Pakistan.
6. Ministry of Finance. (2021). *Economic survey of Pakistan 2020–21* (Chapter 2: Agriculture).
7. Pakistan Meteorological Department. (2019). *Climate data normals of Pakistan (1981–2010)*. Government of Pakistan.
8. United States Department of Agriculture. (2018). *Pakistan: Grain and feed annual*. USDA Foreign Agricultural Service.
9. Water and Power Development Authority. (2020). *Annual report 2019–20*. WAPDA.
10. World Bank. (2019). *Pakistan: Climate change action plan 2019–2030*. World Bank Group.
11. World Wide Fund for Nature Pakistan. (2017). *Living planet report Pakistan 2017*. WWF-Pakistan.

Unit: 8

FARMING SYSTEMS OF PAKISTAN

Compiled by: Dr. Muhammad Rehan
Reviewed by: Dr. Sabir Hussain Shah
Muhammad Fahd Bhatti

CONTENTS

Introduction :..... 115
Objectives : 115
Learning outcomes:..... 115
8.1 Introduction..... 116
8.2 Rice Farming System..... 117
8.3 Rice-Wheat Farming System 118
8.4 Highland Mixed Farming System..... 119
8.5 Rainfed Mixed Farming System 121
8.6 Dry Rainfed Farming System 123
8.7 Pastoral Farming System 126
8.8 Arid Farming System..... 131
8.9 Mountain Farming System..... 134
8.10 Comparative Analysis of Farming Systems..... 139
8.11 Conclusion 140
8.12 Self-Assessment Questions..... 142
8.13 References..... 142

INTRODUCTION :

Pakistan has a wide variety of soils, climates, and water resources, which has led to the development of different farming systems across the country. These systems include irrigated farming, rainfed farming (barani), flood-fed farming, dry farming, and coastal farming, each with its own characteristics, challenges, and cropping patterns.

Understanding farming systems is important because they determine how farmers use land, water, and labor to grow crops and raise livestock. By studying them, we can learn which crops are suitable for different areas, how resources are managed, and what improvements are needed for higher productivity. This knowledge is vital for making agriculture more efficient, sustainable, and supportive of Pakistan's food security and rural economy.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the concept of farming systems and their role in agriculture.
2. Identify and describe the major farming systems of Pakistan, such as irrigated farming, rainfed (barani) farming, dry farming, flood-fed farming, and coastal farming.
3. Highlight the characteristics, cropping patterns, and livestock practices of each farming system.
4. Discuss the advantages and limitations of different farming systems.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. **Define** the concept of farming systems and their significance in agriculture.
2. **Identify and describe** the major farming systems of Pakistan, including irrigated, rainfed (barani), dry, flood-fed, and coastal systems.
3. **Explain** the cropping patterns, livestock practices, and resource use within each farming system.
4. **Compare and contrast** the advantages and limitations of different farming systems.
5. **Analyze** the impact of soil, water, climate, and socio-economic factors on farming systems.

8.1 Introduction

Pakistan's agricultural landscape is characterized by diverse farming systems that have evolved over centuries in response to varying climatic conditions, topography, water availability, and socio-economic factors. These farming systems represent complex integrated approaches to crop and livestock production, each adapted to specific agro-ecological zones and resource constraints. Understanding these systems is crucial for agricultural development, policy formulation, and sustainable resource management.

Agriculture in Pakistan operates across eight distinct farming systems, each with unique characteristics, challenges, and opportunities. These systems collectively support the livelihoods of over 64% of the rural population and contribute approximately 20% to the national GDP. The diversity of these systems reflects Pakistan's varied geography, from the fertile plains of Punjab to the arid deserts of Balochistan and the mountainous terrain of the northern regions.

The farming systems approach recognizes that farmers make integrated decisions about crop selection, livestock management, resource allocation, and risk management within the constraints of their specific environment. This holistic perspective is essential for developing appropriate technologies, policies, and interventions that can enhance productivity, sustainability, and resilience across different agro-ecological zones.

Climate change, population pressure, water scarcity, and market dynamics are placing unprecedented stress on these traditional farming systems. Rising temperatures, erratic rainfall patterns, and extreme weather events are forcing farmers to adapt their practices and crop choices. Simultaneously, urbanization and industrial development are reducing agricultural land, while growing food demand requires increased productivity from remaining farmland.

This unit provides a comprehensive analysis of Pakistan's eight major farming systems: Rice farming system, Rice-wheat farming system, Highland mixed farming system, Rainfed mixed farming system, Dry rainfed farming system, Pastoral farming system, Arid farming system, and Mountain farming system. Each system is examined in terms of its geographical distribution, dominant crops and livestock, production practices, constraints, and potential for improvement.

The analysis emphasizes the need for system-specific approaches to agricultural development, recognizing that solutions effective in one farming system may not be appropriate for another. By understanding the unique characteristics and requirements of each system, policymakers, researchers, and development practitioners can design more targeted and effective interventions to enhance

agricultural productivity, environmental sustainability, and rural livelihoods across Pakistan's diverse agricultural landscape.

8.2 Rice Farming System

8.2.1 Geographic Distribution and Characteristics

The rice farming system is predominantly concentrated in the deltaic regions of Sindh, lower Punjab, and parts of Khyber Pakhtunkhwa, covering approximately 3.2 million hectares. This system is characterized by intensive rice cultivation under irrigated conditions, primarily in areas with flat topography, fine-textured soils, and reliable water supply from the Indus River system.

The system is most prominent in districts such as Larkana, Shikarpur, Sukkur, and Jacobabad in Sindh, and Sheikhupura, Gujranwala, and Sialkot in Punjab. The flat terrain and alluvial soils of these regions provide ideal conditions for rice cultivation, which requires standing water during critical growth stages.

8.2.2 Dominant Crops and Varieties

Rice (Oryza sativa) is the primary crop in this system, typically grown as a single-season Kharif crop from June to November. The main varieties cultivated include:

- **Basmati varieties**: Super Basmati, Basmati 385, and Basmati 198 for export markets
- **IRRI varieties**: IRRI-6, IRRI-9, and KS-282 for domestic consumption
- **Hybrid varieties**: Guard-1, Shaheen Basmati, and improved local varieties

Some areas also practice vegetable cultivation during the Rabi season, including onions, tomatoes, and leafy vegetables, utilizing residual soil moisture and nutrients.

8.2.3 Production Practices

Rice cultivation in this system follows traditional transplanting methods:

- **Land preparation**: Extensive puddling to create impermeable layers for water retention
- **Nursery management**: Seedlings raised in separate nurseries for 25-30 days
- **Transplanting**: Manual transplanting in standing water during June-July
- **Water management**: Continuous flooding was maintained throughout the growing season
- **Fertilizer application**: Heavy use of nitrogenous fertilizers, often

exceeding recommended doses

8.3 Rice-Wheat Farming System

8.3.1 Geographic Distribution and Extent

The rice-wheat farming system is the dominant cropping pattern in the irrigated plains of Punjab and upper Sindh, covering approximately 2.8 million hectares. This intensive system represents the backbone of Pakistan's food security, producing the two most important staple crops in a sequential rotation. The system is most prevalent in districts such as Faisalabad, Sahiwal, Okara, Pak Pattan, and Jhang in Punjab, and Khairpur and Nawabshah in upper Sindh.

This system operates in areas with assured irrigation water supply, predominantly through the canal irrigation network supplemented by tube wells. The flat to gently undulating terrain and deep alluvial soils of the Indus plain provide ideal conditions for this intensive cropping pattern.

8.3.2 Cropping Pattern and Varieties

The system involves a strict rotation of:

- **Kharif season (June-November)**: Rice cultivation
- **Rabi season (November-May)**: Wheat cultivation

Rice varieties grown:

- Fine rice: Basmati varieties for premium markets
- Coarse rice: IRRI varieties for domestic consumption and feed
- Hybrid rice: Increasingly adopted for higher yields

Wheat varieties grown:

- **High-yielding varieties**: Faisalabad-2008, NARC-2009, Punjab-2011
- **Disease-resistant varieties**: Developed to combat rust and other diseases
- **Early maturing varieties**: To fit the tight cropping calendar

8.3.3 Production Technologies

Rice phase:

- Transplanting method with 25-30-day-old seedlings
- Continuous flooding irrigation
- Heavy nitrogen application (120-150 kg/ha)
- Combine harvesting is becoming more common

Wheat phase:

- Zero tillage and conventional tillage practices
- Bed planting is gaining popularity for water savings
- Split application of fertilizers
- Mechanical harvesting through combines

The rice-wheat system provides:

- **Cropping intensity**: 200% (two crops per year)
- **Net returns**: PKR 130,000-140,000 per hectare annually
- **Employment**: 180-220 person-days per hectare per year

8.4 Highland Mixed Farming System

8.4.1 Geographic Distribution and Characteristics

The highland mixed farming system is found in the sub-mountainous and hilly regions of northern Punjab (Potohar Plateau), parts of Khyber Pakhtunkhwa, and Azad Jammu and Kashmir, covering approximately 1.8 million hectares. This system is characterized by diversified crop and livestock production on undulating to steep terrain with elevations ranging from 300 to 1,500 meters above sea level.

The system operates in areas with moderate to high rainfall (500-1,200 mm annually) and is predominantly rainfed, though some areas have access to small-scale irrigation from springs, streams, and tube wells. The topography creates diverse microclimates and soil conditions within short distances, leading to highly diverse farming practices.

8.4.2 Farming Characteristics

Topography and soils:

- Rolling hills and terraced slopes
- Shallow to medium-depth soils with high erosion risk
- Variable soil fertility across elevation gradients

Climate:

- Temperate to subtropical climate
- Cool winters and moderate summers
- Bimodal rainfall pattern with peaks in winter and monsoon

Land use pattern:

- Mixed cropping and intercropping systems
- Integration of crops, trees, and livestock
- Small landholdings (average 2-5 hectares)

8.4.3 Dominant Crops and Production Systems

Food grains:

- **Wheat**: Primary Rabi crop, often grown on terraces
- **Maize**: Main Kharif crop, grown on slopes and valleys
- **Barley**: Grown in higher elevations and marginal lands
- **Millets**: Pearl millet and finger millet in drier areas

Cash crops:

- **Tobacco**: An Important cash crop in suitable areas
- **Oilseeds**: Mustard, sunflower, and groundnut
- **Pulses**: Chickpea, lentil, and field pea
- **Potatoes**: High-value crop in suitable locations

Horticultural crops:

- **Fruits**: Citrus, mango, guava in lower elevations
- **Vegetables**: Tomatoes, onions, chilies, and seasonal vegetables
- **Fodder crops**: Berseem, lucerne, and seasonal grasses

8.4.4 Livestock Integration

Livestock forms an integral component of this farming system:

Cattle and buffalo:

- **Milk production**: 2-5 animals per household
- **Draft power**: Bullocks for field operations
- **Manure production**: Primary source of organic fertilizer

Small ruminants:

- **Goats**: 5-15 animals per household, adapted to browse
- **Sheep**: Smaller numbers, mainly for meat production

Poultry:

- **Backyard chickens**: Indigenous breeds for eggs and meat
- **Commercial poultry**: Small-scale broiler and layer operations

Common intercropping systems:

- Maize + mungbean
- Wheat + mustard (mixed)
- Fruit trees + annual crops (agroforestry)

8.5 Rainfed Mixed Farming System

8.5.1 Geographic Distribution and Extent

The rainfed mixed farming system covers approximately 5.2 million hectares across Pakistan, primarily concentrated in the Potohar Plateau of Punjab, rainfed areas of Khyber Pakhtunkhwa, northern Balochistan, and parts of Sindh. This system is characterized by crop production dependent entirely or predominantly on natural precipitation, with minimal or no irrigation infrastructure.

The system operates in areas receiving 250-750 mm of annual rainfall, with high inter-annual and intra-seasonal variability. The absence of reliable irrigation makes this system highly vulnerable to climate variability and requires careful water conservation and drought management strategies.

8.5.2 Dominant Farming Systems

Crop-livestock integration: The system is characterized by close integration between crop and livestock enterprises, with livestock serving multiple functions including milk production, draft power, manure supply, and risk mitigation.

8.5.3 Crop Production Systems

Wheat cultivation:

- **Varieties**: Drought-tolerant varieties like Chakwal-86, NARC-2009
- **Seeding**: October-November with the onset of winter rains
- **Yield range**: 1.0-2.5 tons/hectare, depending on rainfall
- **Management**: Minimal external inputs, reliance on organic manure

Sorghum and millet production:

- **Varieties**: Local landraces adapted to drought conditions
- **Dual purpose**: Grain and fodder production
- **Sowing**: June-July with monsoon onset

- **Intercropping**: Often grown with pulses for nitrogen fixation

Pulse crops:

- **Chickpea**: Main Rabi pulse crop (120,000 hectares)
- **Lentil**: Grown in cooler areas with better water retention
- **Mungbean**: Summer pulse crop grown with residual moisture
- **Role**: Protein source and soil fertility improvement

8.5.4 Livestock Component

Livestock is an essential component of the rainfed mixed farming system, providing multiple benefits and serving as a buffer against crop failures.

Cattle and buffalo:

- **Population**: 3-8 animals per household
- **Breeds**: Sahiwal, Red Sindhi, and crossbreds
- **Management**: Extensive grazing on communal lands and crop residues
- **Productivity**: Low milk yields (3-8 liters/day) due to poor nutrition

Small ruminants:

- **Goats**: 10-25 animals per household, highly adapted to browse
- **Sheep**: Smaller numbers, mainly for meat and wool
- **Grazing**: Utilize marginal lands and crop residues
- **Market**: Regular source of cash income

Livestock products and services:

- **Milk**: Household consumption and local markets
- **Meat**: Occasional sales and festivals
- **Draft power**: Bullocks for land preparation and transport
- **Manure**: Primary source of organic fertilizer
- **Risk mitigation**: Asset for emergency cash needs

8.5.5 Water Management Strategies

Given the dependence on rainfall, water conservation is critical:

Traditional practices:

- **Fallowing**: Leaving land fallow to conserve moisture

- **Contour farming**: Following land contours to reduce runoff
- **Crop residue management**: Retaining stubble for moisture conservation

Improved techniques:

- **Water harvesting**: Small ponds and check dams
- **Mulching**: Using crop residues to reduce evaporation
- **Tied ridging**: Creating micro-basins for water capture
- **Conservation tillage**: Minimum tillage to preserve soil moisture

8.6 Dry Rainfed Farming System

8.6.1 Geographic Distribution and Characteristics

The dry rainfed farming system operates in the most challenging agricultural environments of Pakistan, covering approximately 6.8 million hectares in southern Punjab, interior Sindh, eastern and southern Balochistan, and parts of southern Khyber Pakhtunkhwa. This system is characterized by extremely limited and erratic rainfall, typically ranging from 100-400 mm annually, with high evapotranspiration rates and frequent drought conditions.

The system is found in areas with arid to semi-arid climates, where agriculture is marginal and highly risky. Despite the challenging conditions, this system supports millions of rural households, primarily through extensive livestock rearing combined with opportunistic crop cultivation during favorable seasons.

8.6.3 Dominant Production Systems

Extensive livestock system: Livestock forms the primary livelihood component, adapted to utilize sparse vegetation and withstand harsh climatic conditions.

Opportunistic crop cultivation: Crop production is highly opportunistic, depending on favorable rainfall events and soil moisture conditions.

8.6.4 Livestock Production

Small ruminant dominance:

- **Goats**: Primary livestock species (15-50 animals per household)
    - Breeds: Beetal, Teddy, Pahari, and local crossbreds
    - Management: Extensive browsing system
    - Products: Milk, meat, hides, and hair
- **Sheep**: Secondary importance (5-20 animals per household)
    - Breeds: Balochi, Bibrik, Harnai, and local types

- Products: Mutton, wool, and skins
- Grazing: Utilize grasslands and crop residues

Cattle and camel production:

- **Cattle**: Limited numbers (1-5 animals per household)
  - Breeds: Red Sindhi, Sahiwal, and local zebu types
  - Management: Semi-intensive system
  - Products: Milk and draft power
- **Camels**: Found in desert areas (1-10 animals per household)
  - Breeds: Marecha, Kohi, and Laresi
  - Services: Transport, draft power, and milk
  - Products: Milk, meat, and hair

8.6.5 Crop Production Systems

Drought-tolerant cereals:

- **Sorghum**: Main staple crop
  - Varieties: Local landraces (Jowari, Charri)
  - Growing season: June-October (if monsoon occurs)
  - Yield: 800-1,500 kg/ha in good years
- **Pearl millet**: Important cereal crop
  - Varieties: Traditional varieties with high drought tolerance
  - Cultivation: Grown with minimal inputs
  - Multiple uses: Grain, fodder, and fuel

Legumes and oilseeds:

- **Cowpea**: Drought-tolerant legume
- **Cluster bean**: Grown for pods and fodder
- **Castor**: Oilseed crop for marginal lands
- **Sesame**: Short-season oilseed crop

Fodder production:

- **Cenchrus grass**: Natural grass harvested and stored

- **Sorghum fodder**: Dual-purpose varieties
- **Acacia pods**: Collected from trees for animal feed

8.6.6 Farming Practices and Adaptations

Water conservation techniques:

- **Rainfall harvesting**: Bund formation and water spreading
- **Crop residue retention**: Mulching for soil moisture conservation
- **Micro-catchments**: Creating small basins to capture runoff
- **Indigenous practices**: Traditional water harvesting methods

Crop management strategies:

- **Opportunistic sowing**: Planting after favorable rainfall events
- **Mixed cropping**: Growing 2-3 crops together for risk distribution
- **Drought escape**: Using short-duration varieties
- **Fallowing**: Leaving fields fallow to accumulate moisture

Livestock management adaptations:

- **Mobility**: Seasonal movement to better grazing areas
- **Feed supplementation**: Using agricultural by-products and wild plants
- **Water management**: Utilizing scattered water sources
- **Breed selection**: Using hardy, drought-tolerant breeds

8.6.10 Adaptation and Development Strategies

Climate resilience building:

- **Drought-resistant varieties**: Development and promotion of climate-resilient crops
- **Water harvesting**: Improved rainwater harvesting and storage systems
- **Early warning systems**: Weather forecasting and drought monitoring
- **Risk management**: Crop and livestock insurance schemes

Livestock development:

- **Breed improvement**: Introduction of more productive and hardy breeds
- **Feed resources**: Development of drought-tolerant fodder crops
- **Health services**: Mobile veterinary services and vaccination programs

- **Value addition**: Meat processing and dairy development

Livelihood diversification:

- **Alternative enterprises**: Handicrafts, small-scale processing
- **Skills development**: Training in non-agricultural activities
- **Microfinance**: Access to credit for income-generating activities
- **Migration support**: Facilitated temporary and seasonal migration

8.7 Pastoral Farming System

8.7.1 Geographic Distribution and Extent

The pastoral farming system covers approximately 4.5 million hectares across Pakistan's extensive rangelands, primarily in Balochistan (75% of the system), southern Punjab, northern Sindh, and parts of Khyber Pakhtunkhwa. This system is characterized by extensive livestock rearing based on natural pastures and seasonal migration patterns that have evolved over centuries.

The system operates in areas receiving 150-500 mm of annual rainfall, characterized by sparse vegetation, harsh climatic conditions, and terrain unsuitable for crop cultivation. Despite covering vast areas, the system supports relatively low human population densities but plays a crucial role in livestock production and rangeland ecosystem management.

8.7.2 Pastoral Communities and Social Structure

Major pastoral tribes:

- **Baloch tribes**: Predominantly in Balochistan
- **Brahui tribes**: Central and southern Balochistan
- **Pashtun tribes**: Northern Balochistan and KP borders
- **Sindhi and Saraiki communities**: Southern Punjab and northern Sindh

Social organization:

- **Clan-based structure**: Extended families forming grazing units
- **Traditional leadership**: Sardars and tribal elders managing resources
- **Collective decision-making**: Grazing rights and migration routes
- **Gender roles**: Men manage large stock, women handle small ruminants

8.7.3 Livestock Species and Management

Small ruminants (dominant):

- **Goats**: 60-70% of total livestock units
  - Major breeds: Beetal, Teddy, Pahari, Kamori
  - Population: 20-100 animals per household
  - Products: Milk, meat, hides, and cashmere
- **Sheep**: 20-25% of total livestock units
  - Breeds: Balochi, Bibrik, Harnai, Kachhi
  - Management: Flocking with goats
  - Products: Mutton, wool, and skins

Large ruminants:

- **Cattle**: Local zebu breeds adapted to harsh conditions
  - Breeds: Red Sindhi, Sahiwal crosses
  - Numbers: 2-8 animals per household
  - Products: Milk, draft power, and beef
- **Camels**: Specialized for desert conditions
  - Breeds: Marecha, Kohi, Laresi
  - Population: 1-15 animals per household
  - Services: Transport, milk, and wool

Poultry: Limited backyard chickens and indigenous birds

8.7.4 Grazing Systems and Migration Patterns

Seasonal migration cycles:

- **Winter grazing** (November-March): Lower elevations and warmer areas
- **Spring movement** (March-May): Following green vegetation
- **Summer grazing** (June-August): Higher elevations and cooler zones
- **Autumn return** (September-November): Gradual movement to winter areas

Grazing management practices:

- **Rotational grazing**: Moving between different pasture areas

- **Mixed species grazing**: Utilizing different vegetation layers
- **Seasonal adjustments**: Adapting herd size to forage availability
- **Traditional rules**: Customary laws governing grazing rights

Migration routes: Well-established traditional routes connecting seasonal grazing areas, often crossing provincial and international boundaries.

8.7.5 Range Resources and Vegetation

Rangeland types:

- **Desert rangelands**: Sparse shrub vegetation (< 200 mm rainfall)
- **Semi-arid rangelands**: Grass-shrub mixed vegetation (200-400 mm rainfall)
- **Sub-humid rangelands**: Better grass coverage (400-600 mm rainfall)
- **Mountain rangelands**: Alpine and subalpine pastures

8.7.6 Production Systems and Productivity

Herd composition (typical pastoral household):

- Goats: 40-80 animals
- Sheep: 20-50 animals
- Cattle: 3-10 animals
- Camels: 2-12 animals (in desert areas)

Annual household production:

- Milk: 2,000-4,000 liters
- Meat: 500-1,200 kg (through sales and slaughter)
- Wool/Hair: 50-150 kg
- Hides/Skins: 30-80 pieces

8.7.7 Economic Performance

Income sources:

- **Livestock sales**: 50-70% of total income
- **Milk and dairy products**: 15-25%
- **Wool, hair, and hides**: 8-15%
- **Non-pastoral activities**: 10-20% (labor, trade, remittances)

Average annual household income: PKR 200,000-500,000 **Income variability**: High, depending on rainfall and market conditions

Marketing patterns:

- **Local markets**: Small animals are sold regularly
- **Urban markets**: Large animals transported to cities
- **Seasonal variations**: Higher sales during festivals and droughts
- **Price fluctuations**: Significant variations throughout the year

8.7.8 Traditional Knowledge and Practices

Indigenous breeding practices:

- **Selective breeding**: Based on productivity and adaptation traits
- **Crossbreeding**: Strategic use of different breeds
- **Genetic conservation**: Maintaining local breed diversity
- **Performance recording**: Oral traditions tracking animal performance

Range management systems:

- **Traditional grazing calendars**: Based on seasonal forage availability
- **Customary laws**: Regulating access to water and grazing areas
- **Conflict resolution**: Traditional mechanisms for resource disputes
- **Conservation practices**: Protecting vegetation during drought

Healthcare practices:

- **Ethno-veterinary medicine**: Use of local plants for treatment
- **Preventive measures**: Traditional vaccination and health practices
- **Quarantine systems**: Isolating sick animals
- **Nutritional supplements**: Using salt licks and mineral sources

8.7.9 Major Challenges and Constraints

Environmental degradation:

- **Overgrazing**: Exceeding the carrying capacity in many areas
- **Range deterioration**: Decline in palatable species
- **Soil erosion**: Accelerated by overuse and extreme weather
- **Desertification**: Expansion of desert conditions

Climate change impacts:

- **Increased drought frequency**: More severe and prolonged droughts
- **Temperature extremes**: Higher heat stress on livestock
- **Erratic rainfall**: Disrupting traditional migration patterns
- **Extreme weather events**: Flash floods and severe storms

Socio-economic pressures:

- **Land use conflicts**: Competition with agriculture and mining
- **Restricted mobility**: Border controls and land ownership changes
- **Market access**: Poor infrastructure and transportation
- **Population pressure**: Increasing human and livestock populations

Institutional weaknesses:

- **Weak governance**: Limited government support and services
- **Lack of representation**: Marginalized in policymaking
- **Poor service delivery**: Inadequate veterinary and extension services
- **Land tenure issues**: Uncertain grazing rights and access

8.7.10 Development Opportunities and Strategies

Sustainable rangeland management:

- **Carrying capacity assessment**: Scientific determination of sustainable stocking rates
- **Range improvement**: Reseeding with improved grass species
- **Water development**: Strategic placement of water points
- **Grazing management**: Rotational and deferred grazing systems

Livestock productivity enhancement:

- **Breed improvement**: Crossbreeding programs with superior breeds
- **Health services**: Mobile veterinary units and vaccination programs
- **Feed supplementation**: Strategic feeding during critical periods
- **Record keeping**: Introduction of simple performance recording systems

Market development:

- **Value chain improvement**: Better processing and marketing facilities

- **Quality standards**: Meeting export and urban market requirements
- **Price information systems**: Real-time market price dissemination
- **Cooperative formation**: Collective bargaining and bulk marketing

Livelihood diversification:

- **Skill development**: Training in alternative income sources
- **Microenterprises**: Small-scale processing and handicrafts
- **Tourism**: Eco-tourism and cultural tourism opportunities
- **Renewable energy**: Solar and wind power for remote communities

8.8 Arid Farming System

8.8.1 Geographic Distribution and Characteristics

The arid farming system encompasses approximately 8.2 million hectares across Pakistan's most challenging agricultural environments, primarily in central and southern Balochistan, parts of southern Punjab, western Sindh, and southern Khyber Pakhtunkhwa. This system operates under extreme water scarcity conditions, with annual precipitation typically below 250 mm and potential evapotranspiration exceeding 2,000 mm.

The system is characterized by scattered oasis cultivation, utilization of ephemeral water sources, and highly specialized drought-adapted agricultural practices. Despite the harsh environment, this system supports significant populations through ingenious water management techniques and the cultivation of specially adapted crops.

8.8.3 Water Management Systems

Traditional irrigation methods:

- **Karez/Qanat systems**: Ancient underground water channels
    - Length: 2-50 kilometers from the source to the fields
    - Maintenance: Community-based management systems
    - Water rights: Complex traditional sharing arrangements
    - Sustainability: Some systems are over 1,000 years old
- **Sailaba cultivation**: Flood irrigation utilizing ephemeral streams
    - Seasonal: Dependent on occasional rainfall events
    - Infrastructure: Simple diversion structures and channels
    - Crops: Quick-maturing varieties planted after floods

- Risk: High variability and uncertainty

Modern water technologies:

- **Drip irrigation**: High-efficiency systems for high-value crops
- **Solar-powered pumps**: Sustainable groundwater extraction
- **Water harvesting**: Collection and storage of scarce rainfall
- **Desalination**: Small-scale treatment of saline groundwater

8.8.4 Cropping Systems and Crop Selection

Date palm cultivation: The cornerstone of arid farming systems, providing both food and environmental protection.

- **Varieties**: Khajoor, Dhakki, Begum Jangi, Halawi
- **Intercropping**: Vegetables, fodder crops, and cereals grown under the palm canopy
- **Yields**: 50-150 kg per tree annually
- **Multiple products**: Dates, palm wine, leaves for crafts, timber

Drought-tolerant cereals:

- **Pearl millet**: Extremely drought-tolerant, 90-120 day maturity
- **Sorghum**: Adapted varieties with low water requirements
- **Barley**: , Cool-season crop utilizing winter moisture
- **Wheat**: Limited cultivation in areas with assured irrigation

Legumes and oilseeds:

- **Cowpea**: Heat and drought- tolerant, nitrogen-fixing
- **Cluster bean**: Drought-resistant, multiple harvest potential
- **Castor**: Perennial oilseed crop for marginal conditions
- **Chickpea**: Winter crop in areas with residual moisture

Vegetables and cash crops:

- **Onions**: High-value crop with storage potential
- **Chilies**: Drought-tolerant and high market value
- **Melons**: Utilizing stored soil moisture
- **Cumin**: Spice crop adapted to arid conditions

8.8.5 Livestock Integration

Adapted livestock species:

- **Camels**: Highly specialized for desert conditions
    - Breeds: Marecha (dual-purpose), Kohi (racing), Laresi (pack)
    - Products: Milk (nutritious), meat, hair, transportation
    - Management: Extensive grazing on desert vegetation
- **Goats**: Hardy breeds adapted to browse
    - Breeds: Kamori, Tapri, Barbari crosses
    - Management: Semi-intensive with supplementary feeding
    - Products: Milk, meat, hides for local and urban markets
- **Sheep**: Fat-tailed breeds for harsh conditions
    - Breeds: Balochi and Mengali are adapted to heat and water scarcity
    - Products: Mutton, wool, skins
    - Grazing: Utilize desert shrubs and crop residues

8.8.6 Production Systems and Management

Oasis agriculture: Intensive cultivation around permanent water sources creates productive micro-environments.

- **Multi-story systems**: Date palms, fruit trees, crops, and vegetables
- **Soil management**: Organic matter addition and mulching
- **Microclimate**: Palm canopy creating cooler, more humid conditions
- **Water efficiency**: Precise application and recycling systems

Nomadic cultivation: Opportunistic farming following rainfall events and seasonal water availability.

- **Mobile systems**: Temporary cultivation with simple tools
- **Quick maturity**: Fast-growing crops complete their cycle rapidly
- **Risk spreading**: Multiple small plots in different locations
- **Flexible timing**: Planting based on moisture conditions

8.8.10 Adaptation and Development Strategies

Water resource development:

- **Groundwater management**: Sustainable extraction and recharge

- **Efficiency improvement**: Drip and micro-irrigation systems
- **Alternative sources**: Rainwater harvesting and recycling
- **Technology adoption**: Solar pumps and precision irrigation

Crop and variety development:

- **Breeding programs**: Developing more drought-tolerant varieties
- **Crop diversification**: Introduction of high-value, adapted crops
- **Integrated systems**: Combining annual crops with perennials
- **Biotechnology**: Genetic modification for stress tolerance

Livelihood enhancement:

- **Value addition**: Processing of dates and other products
- **Market linkages**: Direct connections to urban and export markets
- **Skill development**: Training in modern farming and non-farm activities
- **Microfinance**: Access to credit for productive investments

Environmental sustainability:

- **Conservation practices**: Soil and water conservation techniques
- **Renewable energy**: Solar and wind power systems
- **Ecosystem restoration**: Rehabilitation of degraded rangelands
- **Climate adaptation**: Early warning systems and adaptive practices

8.9 Mountain Farming System

8.9.1 Geographic Distribution and Extent

The mountain farming system covers approximately 2.1 million hectares across Pakistan's northern mountainous regions, including Gilgit-Baltistan, northern areas of Khyber Pakhtunkhwa, Azad Jammu and Kashmir, and the northern districts of Punjab. This system operates at elevations ranging from 1,000 to 4,500 meters above sea level, encompassing diverse ecological zones from temperate valleys to alpine pastures.

The system is characterized by extreme topographical diversity, with steep slopes, narrow valleys, and highly variable microclimates within short distances. Despite challenging terrain and harsh winters, this system supports over 2 million people through ingenious agricultural practices adapted to mountain conditions.

8.9.2 Agro-ecological Zones

Temperate zone (1,000-2,500m):

- **Climate**: Moderate temperatures, adequate rainfall/snowfall
- **Crops**: Wheat, maize, barley, vegetables, fruit trees
- **Vegetation**: Mixed forests of oak, pine, and deciduous species
- **Growing season**: 150-180 days

Sub-alpine zone (2,500-3,500m):

- **Climate**: Cool summers, severe winters with heavy snowfall
- **Crops**: Barley, potatoes, limited vegetables
- **Vegetation**: Coniferous forests and alpine shrubs
- **Growing season**: 90-120 days

Alpine zone (3,500-4,500m):

- **Climate**: Short, cool summers, extreme winters
- **Land use**: Seasonal grazing, limited cultivation
- **Vegetation**: Alpine grasses and hardy shrubs
- **Growing season**: 60-90 days

8.9.3 Cropping Systems and Agricultural Practices

Cereal production:

- **Wheat**: Primary food grain, grown in terraced fields
    - Varieties: High-altitude-adapted varieties like Tatara, Pirsabak-2004
    - Cultivation: Spring planting (March-April), autumn harvest
    - Yields: 1.5-2.8 tons/ha depending on elevation
- **Maize**: Important summer crop in lower elevations
    - Varieties: Local landraces and improved composites
    - Intercropping: Often grown with beans and pumpkins
    - Multiple uses: Grain, fodder, and fuel
- **Barley**: Hardy crop for higher elevations
    - Varieties: Six-row hulless varieties preferred

- Adaptation: Extreme cold and short-season tolerance
- Uses: Food, fodder, and brewing

Cash crops and vegetables:

- **Potatoes**: Major cash crop and food security crop
  - Production: 15-25 tons/ha in suitable areas
  - Storage: Traditional storage in underground pits
  - Marketing: Supply to lowland urban markets
- **Vegetables**: High-value crops for market sales
  - Summer vegetables: Tomatoes, onions, chilies, beans
  - Winter vegetables: Leafy greens, radishes, turnips
  - Protected cultivation: Poly tunnels for season extension

Fruit production: Mountain areas are renowned for high-quality fruits adapted to temperate climates.

- **Apples**: Premium varieties with excellent keeping quality
  - Varieties: Red Delicious, Golden Delicious, local selections
  - Yields: 8-15 tons/ha in mature orchards
  - Export potential: High value in national and international markets
- **Stone fruits**: Apricots, cherries, plums, peaches
  - Fresh consumption: Local and regional markets
  - Processing: Dried fruits and preserved products
  - Nutritional value: High vitamin and mineral content
- **Nuts**: Walnuts, almonds in suitable microclimates
  - Traditional varieties: Adapted to local conditions
  - Income generation: An Important cash source for households
  - Value addition: Processing and direct marketing

8.9.4 Livestock Systems

Cattle and buffalo:

- **Breeds**: Local mountain breeds adapted to altitude and cold
  - Holstein-Friesian crosses at lower elevations

    - Traditional breeds like Achai in remote areas
- **Management**: Stall-feeding during winter, grazing in summer
- **Products**: Milk for household consumption and cheese making

Small ruminants:

- **Goats**: Hardy breeds like Kaghani and local types
    - Summer grazing: High-altitude pastures
    - Winter feeding: Stored fodder and crop residues
    - Products: Milk, meat, and mohair
- **Sheep**: Fat-tailed breeds adapted to mountain conditions
    - Transhumance: Seasonal movement between elevations
    - Products: Wool, meat, and milk
    - Grazing management: Rotational use of alpine pastures

Yaks and crossbreeds:

- **High-altitude areas**: Above 3,000 meters in elevation
- **Breeds**: Pure yaks and yak-cattle crossbreeds (dzos)
- **Products**: Milk, meat, hair, and pack animals
- **Adaptation**: Extreme cold and low oxygen conditions

8.9.5 Agricultural Innovations and Techniques

Terracing and land management:

- **Stone terraces**: Extensive terracing to create cultivable land
- **Soil conservation**: Preventing erosion on steep slopes
- **Water management**: Channel systems for irrigation
- **Maintenance**: Community-based terrace maintenance systems

Irrigation systems:

- **Glacier-fed channels**: Traditional irrigation from glacial streams
- **Spring water utilization**: Harnessing natural springs
- **Water sharing**: Complex traditional water rights systems
- **Seasonal management**: Adjusting to variable water availability

Crop diversification:

- **Multiple cropping**: Different crops at various elevations
- **Intercropping**: Maximizing land use efficiency
- **Agroforestry**: Integration of trees with agricultural crops
- **Kitchen gardens**: Intensive vegetable production near homes

8.9.9 Development Opportunities

High-value agriculture:

- **Organic production**: Natural conditions are favorable for organic farming
- **Premium fruits**: Apples and stone fruits with export potential
- **Off-season vegetables**: Protected cultivation for higher prices
- **Medicinal plants**: Wild and cultivated herbs with commercial value

Agro-tourism integration:

- **Farm stays**: Authentic mountain farming experiences
- **Fruit picking**: Seasonal tourism activities
- **Traditional foods**: Marketing local cuisine and products
- **Cultural tourism**: Integration with local traditions

Technology adoption:

- **Greenhouse cultivation**: Season extension and crop diversification
- **Drip irrigation**: Water-efficient systems for high-value crops
- **Solar energy**: Renewable energy for farming operations
- **Cold storage**: On-farm storage for extended marketing

8.9.10 Sustainable Development Strategies

Climate adaptation:

- **Resilient varieties**: Development of climate-adapted crops
- **Diversification**: Reducing risks through multiple enterprises
- **Water management**: Efficient use of limited water resources
- **Early warning**: Weather forecasting and disaster preparedness

Infrastructure development:

- **Rural roads**: Improved connectivity to markets

- **Communication**: Internet and mobile coverage
- **Processing facilities**: Value addition at the local level
- **Storage infrastructure**: Reduce post-harvest losses

Institutional strengthening:

- **Farmer organizations**: Collective bargaining and resource sharing
- **Extension services**: Technical support for mountain agriculture
- **Credit access**: Financial services for agricultural development
- **Research support**: Mountain-specific agricultural research

Environmental conservation:

- **Sustainable practices**: Soil and water conservation
- **Biodiversity protection**: Maintaining genetic resources
- **Forest management**: Sustainable use of forest resources
- **Ecosystem services**: Recognizing environmental benefits

8.10 Comparative Analysis of Farming Systems

8.10.2 Production Contribution

Food security contribution:

- **Rice-wheat system**: Provides 70% of staple food production
- **Rice system**: Contributes 25% of national rice production
- **Mountain system**: Supplies premium fruits and vegetables
- **Other systems**: Provide livestock products and coarse grains

Economic importance:

- **Irrigated systems** (Rice, Rice-wheat): Generate 60% of agricultural GDP
- **Rainfed systems**: Support 40% of the rural population
- **Pastoral systems**: Provide 30% of national livestock production

8.10.3 Sustainability Assessment

Resource use efficiency:

- **Highest efficiency**: Mountain and Highland mixed systems
- **Moderate efficiency**: Rainfed and Pastoral systems
- **Low efficiency**: Rice-wheat and Arid systems

- **Improving trend**: Adoption of conservation practices

Environmental impact:

- **High pressure**: Rice-wheat system (soil, water degradation)
- **Moderate pressure**: Intensive rice and Highland systems
- **Low pressure**: Extensive pastoral and mountain systems
- **Restoration potential**: All systems with proper management

8.11 Conclusion

Pakistan's eight distinct farming systems represent a remarkable diversity of agricultural adaptation to varied environmental, climatic, and socio-economic conditions. Each system has evolved over centuries to optimize production within specific constraints, developing unique practices, crop varieties, and management strategies that reflect local conditions and farmer innovation.

The analysis reveals both the strengths and vulnerabilities of these systems in the face of mounting challenges. The intensive irrigated systems (Rice and Rice-wheat) form the backbone of national food security but face serious sustainability concerns related to resource depletion and environmental degradation. The extensive systems (Pastoral, Arid, and Dry rainfed) support large populations under harsh conditions but struggle with low productivity and climate vulnerability.

Key findings across systems:

Diversity as strength: The diversity of farming systems provides resilience against various shocks and contributes to national food and nutrition security through different pathways.

Climate vulnerability: All systems show increasing vulnerability to climate change, but adaptive capacity varies significantly based on resource availability and institutional support.

Technology gaps: Significant potential exists for productivity improvements through appropriate technology adoption, but access and adoption rates remain low in many systems.

Market integration: Better market linkages and value addition opportunities exist across all systems, particularly for high-value products and niche markets.

Resource management: Sustainable resource management practices are critical for long-term viability, requiring system-specific approaches and technologies.

Policy implications: Different farming systems require differentiated policy approaches rather than one-size-fits-all solutions.

Future directions for development:

System-specific interventions: Develop targeted strategies that address the unique constraints and opportunities of each farming system.

Climate adaptation: Integrate climate resilience building into all farming systems through appropriate varieties, practices, and risk management tools.

Technology integration: Promote precision agriculture, digital tools, and mechanization appropriate to each system's scale and conditions.

Value chain development: Strengthen linkages between producers and markets, emphasizing quality, processing, and branding opportunities.

Institutional strengthening: Build farmer organizations, cooperatives, and service delivery systems tailored to each farming system's needs.

Research and development: Focus research efforts on system-specific challenges and opportunities, including participatory approaches with farmers. Success in transforming these farming systems will require coordinated efforts from policymakers, researchers, extension services, the private sector, and farmers themselves.

8.12 Self-Assessment Questions

1. Shaheen Basmati is a variety of _____crop.
2. Rice-what cropping system covers approximately _____ area.
3. Punjab-2011 is a variety of _____crop
4. Charri is local name of _____crop.
5. Early warning systems are responsible for forecasting of _____.

Answers

1) Rice 2) 2.8 million hectares 3) Wheat 4) Sorghum 5) Weather

8.13 References

1. Food and Agriculture Organization of the United Nations. (2023). *Country profile: Pakistan*. FAO.
2. International Food Policy Research Institute. (2024). *Pakistan agricultural outlook*. IFPRI.
3. Mahmood, M., Chaudhry, A., Sajid, S., Fatima, A. N., & Qasim, S. (2024). *State of the Pakistan economy: Growth, inflation, welfare, and the budget (Financial year 2024)*. Government of Pakistan.
4. Ministry of Climate Change. (2024). *Climate change and agriculture in Pakistan*. Government of Pakistan.
5. Ministry of Finance. (2024–2025). *Pakistan economic survey 2024–25*. Government of Pakistan.
6. Ministry of National Food Security and Research. (2018). *National agricultural policy*. Government of Pakistan.
7. Provincial Agricultural Departments. (2024). *Crop production reports*. Government of Pakistan.
8. Water and Power Development Authority. (2024). *Water resources data*. WAPDA.

Unit: 9

AGRO-BASED INDUSTRIES OF PAKISTAN

Compiled by: Dr. Muhammad Rehan
Reviewed by: Dr. Sabir Hussain Shah
Muhammad Fahd Bhatti

CONTENTS

Introduction :..... 145
Objectives : 145
Learning outcomes:..... 145
9.1 Introduction..... 146
9.2 Cotton and Textile Industry 147
9.3 Wheat Flour Industry 153
9.4. Rice Industry..... 159
9.5 Sugar Industry..... 166
9.6 Maize Processing Industry..... 173
9.7 Self-Assessment Questions..... 177
9.8 References..... 178

INTRODUCTION :

Agro-based industries are those industries that use agricultural raw materials to produce goods for domestic use and export. In Pakistan, these industries play a vital role in strengthening the economy because agriculture provides abundant raw materials like cotton, sugarcane, wheat, fruits, milk, and livestock products. Major agro-based industries include the textile industry, sugar industry, flour mills, dairy and meat processing, fruit and vegetable processing, and the leather industry.

Studying agro-based industries is important because they create employment opportunities, add value to agricultural products, support rural development, and contribute significantly to national income and exports. Understanding their role and challenges helps in planning better linkages between agriculture and industry for sustainable economic growth in Pakistan.

OBJECTIVES :

The main objectives of this unit are to:

1. Explain the concept and importance of agro-based industries in Pakistan's economy.
2. Identify the major agro-based industries such as textiles, sugar, flour, dairy, fruit and vegetable processing, and leather.
3. Describe the link between agriculture and industry, highlighting how raw materials are processed into value-added products.
4. Discuss the role of agro-based industries in employment generation, rural development, and export earnings.

LEARNING OUTCOMES:

By the end of this unit, students will be able to:

1. **Define and explain** the concept of agro-based industries and their significance in Pakistan.
2. **Identify and describe** the major agro-based industries such as textiles, sugar, flour, dairy, leather, and fruit/vegetable processing.
3. **Explain** the interdependence of agriculture and industry through the use of raw materials and value addition.
4. **Analyze** the contribution of agro-based industries to employment, rural development, and exports.

9.1 Introduction

Agro-based industries form the backbone of Pakistan's manufacturing sector and play a pivotal role in the country's economic development. These industries process agricultural raw materials into finished or semi-finished products, creating value addition, employment opportunities, and export earnings. Pakistan's agro-based industrial sector has evolved significantly since independence, leveraging the country's strong agricultural base to develop a diverse range of processing industries.

The agro-industrial sector contributes approximately 68% to Pakistan's total manufacturing output and accounts for nearly 16% of the Gross Domestic Product (GDP). According to the Pakistan Bureau of Statistics (2024-25), agro-based industries employ over 3.5 million people directly and support millions more through backward and forward linkages. These industries are crucial for rural development as they create demand for agricultural products, provide employment in rural and semi-urban areas, and facilitate technology transfer.

Pakistan's strategic location, abundant agricultural resources, and relatively low labor costs provide competitive advantages for agro-based industries. The country is among the world's leading producers of cotton, rice, wheat, sugarcane, and various fruits and vegetables, providing a strong raw material base for industrial processing. The diversity of agro-climatic zones enables year-round production of different crops, ensuring a consistent supply to processing industries.

The major agro-based industries in Pakistan include cotton and textile manufacturing, wheat flour milling, rice processing, sugar production, maize processing, vegetable oil and ghee manufacturing, dairy processing, and the poultry industry. Each of these industries has developed distinct characteristics, faces unique challenges, and contributes differently to the national economy.

Historical development: The agro-industrial sector began with simple processing units during the British colonial period, focusing mainly on cotton ginning and wheat milling. Post-independence industrialization policies emphasized import substitution and export promotion, leading to the rapid expansion of textile, sugar, and other agro-processing industries. The Green Revolution of the 1960s-70s provided increased raw material availability, spurring further industrial growth.

Current significance: Today, Pakistan's agro-based industries are integral to the country's export economy, with textiles alone accounting for over 60% of total export earnings. These industries have also become important for domestic food security, processing significant portions of major crops for local consumption and creating value-added products.

Global integration: Pakistani agro-industries are increasingly integrated into global value chains, particularly in textiles, rice, and sports goods. This integration brings opportunities for technology transfer, quality improvements, and market expansion, but also exposes domestic industries to international competition and market volatility.

Structural transformation: The sector is undergoing structural transformation with the consolidation of processing units, adoption of modern technologies, emphasis on quality standards, and development of specialized products for niche markets. Environmental sustainability and social responsibility are becoming increasingly important considerations.

Policy framework: Government policies have significantly influenced the development of agro-based industries through trade policies, investment incentives, credit facilities, and regulatory frameworks. Recent policy emphasis has been on value addition, export diversification, and the development of small and medium enterprises (SMEs) in the agro-processing sector.

This unit provides a comprehensive analysis of Pakistan's major agro-based industries, examining their structure, performance, challenges, and potential for future growth. Each industry is analyzed in terms of raw material supply, processing technologies, market dynamics, export performance, and development constraints. The analysis emphasizes the linkages between agricultural production and industrial processing, highlighting opportunities for strengthening value chains and improving competitiveness.

Understanding these industries is crucial for policymakers, investors, researchers, and development practitioners working to enhance Pakistan's economic development through agricultural industrialization. The unit also discusses emerging trends, technological innovations, and policy reforms needed to modernize and expand Pakistan's agro-industrial base in response to changing domestic and international market conditions.

9.2 Cotton and Textile Industry

9.2.1 Overview and Significance

The cotton and textile industry represents the largest and most important agro-based industry in Pakistan, serving as the backbone of the country's manufacturing sector and export economy. This industry encompasses the entire value chain from cotton cultivation to finished textile products, including ginning, spinning, weaving, dyeing, printing, and garment manufacturing.

Economic importance:

- Contributes approximately 8.5% to GDP and 45% to the manufacturing

sector

- Accounts for over 60% of total export earnings (approximately $15.4 billion in 2023-24)
- Employs over 15 million people directly and indirectly (40% of the industrial workforce)
- Supports 1.5 million farming families through cotton cultivation
- Generates substantial foreign exchange earnings and supports the balance of payments

Global position: Pakistan ranks as the world's 4th largest cotton producer, 3rd largest cotton consumer, and 2nd largest exporter of cotton yarn. The country is also among the top 10 textile exporters globally, with significant market presence in the United States, the European Union, and emerging markets.

9.2.2 Raw Material Base - Cotton Production

Cotton cultivation: Pakistan cultivates cotton on approximately 2.5-3.0 million hectares annually, primarily in Punjab (70%) and Sindh (30%). The crop is grown in both irrigated and barani (rainfed) areas, with irrigated cotton accounting for over 85% of total production.

Production statistics (2023-24):

- **Total production**: 9.7 million bales (170 kg each)
- **Average yield**: 758 kg/hectare (lint yield)
- **Quality parameters**: Staple length 1.0-1.2 inches, micronaire 3.8-4.9
- **Varieties**: Bt cotton varieties dominate (95% of area)

9.2.3 Industry Structure and Value Chain

Cotton ginning:

- **Number of units**: Approximately 1,249 ginning factories
- **Processing capacity**: 15.2 million bales annually
- **Technology**: Mix of traditional and modern ginning equipment
- **Geographic distribution**: Concentrated in cotton-growing districts
- **Products**: Cotton lint, cottonseed, and cotton waste

Spinning industry:

- **Installed capacity**: 11.5 million spindles
- **Production**: 3.2 billion kg of yarn annually

- **Product range**: Carded, combed, and open-end yarn (Ne 10s to Ne 80s)
- **Technology levels**: Mix of conventional and modern spinning systems
- **Major hubs**: Faisalabad, Karachi, Lahore, and Multan

Weaving sector:

- **Power looms**: Over 400,000 units
- **Shuttleless looms**: Approximately 15,000 units
- **Production**: 950 million square meters of fabric annually
- **Product types**: Denim, sheeting, canvas, drill, and specialty fabrics
- **Integration levels**: Varying from composite mills to specialized units

Processing and finishing:

- **Dyeing units**: Over 500 facilities
- **Printing units**: 200+ facilities
- **Processing capacity**: 1.2 billion meters annually
- **Technologies**: Conventional and eco-friendly processing methods
- **Standards**: Increasing focus on international quality certifications

9.2.4 Product Portfolio and Markets

Yarn exports:

- **Volume**: 450,000 tons annually
- **Value**: $1.8 billion
- **Major markets**: China (40%), Turkey (12%), South Korea (10%)
- **Product mix**: Cotton yarn dominates (85%), blended yarns growing

Fabric exports:

- **Volume**: 180 million square meters
- **Value**: $1.2 billion
- **Product categories**: Denim, canvas, and specialized fabrics
- **Markets**: Europe (35%), Middle East (25%), Africa (20%)

Garment and made-up exports:

- **Value**: $12.4 billion (80% of textile exports)
- **Product categories**:

- Ready-made garments: $4.8 billion
- Knitwear: $3.6 billion
- Bed wear: $2.1 billion
- Towels: $0.7 billion
- Other made-ups: $1.2 billion

Major export destinations:

Market	Share (%)	Value ($ billion)
USA	25	3.85
Germany	8	1.23
UK	7	1.08
Spain	6	0.92
Netherlands	5	0.77
Others	49	7.55

9.2.5 Technology and Innovation

Modernization initiatives:

- **Machinery upgrades**: $2.5 billion invested in the last decade
- **Automation**: Increasing adoption of automated systems
- **Digital integration**: Implementation of Industry 4.0 concepts
- **Energy efficiency**: Focus on reducing energy consumption per unit

Research and development:

- **Pakistan Cotton Standards Institute**: Quality testing and research
- **Textile institutes**: Technical education and training programs
- **International collaborations**: Technology transfer partnerships
- **Product development**: Focus on high-value specialty products

Sustainability measures:

- **Organic cotton**: Growing but limited (2% of production)
- **Water management**: Adoption of water-efficient processing

- **Cleaner production**: Investment in eco-friendly technologies
- **Certifications**: Increasing compliance with international standards

9.2.6 Major Challenges

Raw material constraints:

- **Production variability**: Cotton output fluctuates due to weather and pests
- **Quality issues**: Contamination, short staple length, and micronaire problems
- **Cost competitiveness**: High input costs affect farmer profitability
- **Ginning problems**: Outdated ginning is causing quality deterioration

Manufacturing challenges:

- **Energy costs**: High electricity and gas tariffs are affecting competitiveness
- **Technology gaps**: Outdated machinery in many units
- **Skilled labor shortage**: Limited availability of trained workforce
- **Working capital**: High interest rates and limited financing options

Market challenges:

- **Competition**: Intense competition from Bangladesh, Vietnam, and India
- **Trade barriers**: Tariffs and non-tariff barriers in international markets
- **Compliance costs**: Increasing requirements for certifications and standards
- **Currency fluctuations**: Exchange rate volatility affecting export earnings

Infrastructure constraints:

- **Power supply**: Frequent outages and voltage fluctuations
- **Transportation**: High logistics costs and port congestion
- **Water availability**: Scarcity affecting processing operations
- **Environmental compliance**: Increasing regulatory requirements

9.2.7 Government Support and Policies

Policy framework:

- **Textile Policy 2020-25**: Comprehensive strategy for sector development
- **Export facilitation**: Duty-free imports of machinery and inputs

- **Energy subsidies**: Subsidized electricity and gas for export industries
- **Technology upgradation**: Concessional financing for modernization

Institutional support:

- **Export Promotion Bureau**: Trade promotion and market development
- **Textile Development Board**: Industry development and support
- **Pakistan Readymade Garment Manufacturers Association**: Industry representation
- **All Pakistan Textile Mills Association**: Policy advocacy and services

Financial incentives:

- **Export refinance scheme**: Concessional financing for exporters
- **Long-term financing**: Equipment financing at subsidized rates
- **Tax incentives**: Reduced corporate tax rates for exporters
- **Duty drawbacks**: Refund of customs duties on imported inputs

9.2.8 Future Prospects and Development Strategy

Growth opportunities:

- **Market expansion**: Penetration in emerging markets and product diversification
- **Value addition**: Moving up the value chain to branded products
- **Technical textiles**: Development of specialized industrial textiles
- **Regional integration**: Leveraging CPEC and regional trade agreements

Strategic priorities:

- **Cotton productivity**: Improving yield and quality through better varieties and practices
- **Technology modernization**: Upgrading machinery and adopting digital technologies
- **Human resource development**: Skills training and capacity building programs
- **Sustainability compliance**: Adopting environmental and social standards

Investment requirements:

- **Machinery modernization**: $5 billion over the next 5 years

- **Infrastructure development**: Power, water, and transportation facilities
- **Research and development**: Enhanced R&D capabilities and innovation
- **Human capital**: Technical education and skills development programs

Target achievements by 2030:

- **Export value**: $25 billion (62% increase from current levels)
- **Employment**: 20 million jobs (33% increase)
- **Value addition**: Increase share of finished products to 70%
- **Productivity**: 25% improvement in labor and energy productivity

9.3 Wheat Flour Industry

9.3.1 Industry Overview and Significance

The wheat flour industry is one of the most essential agro-based industries in Pakistan, directly linked to the food security and nutrition of over 240 million people. This industry processes wheat, the country's most important cereal crop, into flour and various by-products for domestic consumption and export markets.

Economic importance:

- **Processing volume**: 26-28 million tons of wheat annually
- **Industry value**: Approximately PKR 2.5 trillion ($12 billion)
- **Employment**: Over 0.5 million people are directly employed
- **Market size**: 99% of wheat production is processed domestically
- **Export contribution**: $180-220 million annually

Strategic significance: Wheat flour is the staple food for the majority of Pakistan's population, making this industry critical for food security, price stability, and social welfare. The industry also serves as an important link between farmers and consumers, facilitating the transformation of agricultural produce into consumer-ready products.

9.3.2 Raw Material Base - Wheat Production

Wheat production overview: Pakistan is among the world's top 8 wheat producers, with wheat being the largest crop by area and the second-largest by production value. The crop is grown in both irrigated and rainfed conditions across all provinces.

Production statistics (2023-24):

- **Total area**: 9.0 million hectares

- **Total production**: 28.2 million tons
- **Average yield**: 3.13 tons/hectare
- **Irrigated area**: 7.2 million hectares (80%)
- **Rainfed area**: 1.8 million hectares (20%)

Provincial production distribution:

Province	Area (000 ha)	Production (000 tons)	Yield (tons/ha)
Punjab	6,800	20,100	2.96
Sindh	1,200	4,200	3.50
KP	750	1,400	1.87
Balochistan	250	500	2.00
Total	**9,000**	**26,200**	**2.91**

Wheat varieties and quality:

- **High-yielding varieties**: Faisalabad-2008, NARC-2009, Punjab-2011
- **Quality parameters**: Protein content 10-14%, gluten 24-32%
- **Classification**: Hard wheat (65%), soft wheat (35%)
- **Post-harvest handling**: Traditional and modern storage systems

9.3.3 Industry Structure and Processing

Mill classification and capacity: The wheat flour industry consists of large-scale, medium-scale, and small-scale mills with varying technologies and capacities.

Large-scale mills (capacity >200 tons/day):

- **Number**: 95 mills
- **Total capacity**: 32,000 tons/day
- **Technology**: Modern pneumatic and roller mills
- **Market share**: 35% of total processing
- **Geographic concentration**: Major urban centers

Medium-scale mills (capacity 50-200 tons/day):

- **Number**: 450 mills

- **Total capacity**: 35,000 tons/day
- **Technology**: Semi-automatic roller mills
- **Market share**: 40% of total processing
- **Distribution**: Semi-urban and district centers

Small-scale mills (capacity <50 tons/day):

- **Number**: 25,000+ mills
- **Total capacity**: 45,000 tons/day
- **Technology**: Traditional chakki and small roller mills
- **Market share**: 25% of total processing
- **Coverage**: Rural areas and small towns

Processing technology:

- **Traditional chakki mills**: Stone grinding, whole wheat flour
- **Modern roller mills**: Gradual reduction, refined flour production
- **Pneumatic systems**: Automated handling and sifting
- **Quality control**: Laboratory testing and standardization

3.4 Product Portfolio and Utilization

Primary products:

- **Whole wheat flour**: 72-76% extraction rate, retains bran and germ
- **White flour**: 68-72% extraction rate, refined product
- **Semolina (Suji)**: Coarse particles for specific food applications
- **Fine flour**: High-grade flour for bakery and confectionery

By-products:

- **Wheat bran**: 18-22% of grain weight, used for animal feed
- **Wheat germ**: 2-3% of grain weight, oil extraction and nutrition
- **Middlings**: Mixed particles used in feed formulations
- **Dust and screenings**: Lower-grade feed ingredients

End-use applications:

Product	Utilization (%)	Primary Uses
Household consumption	70	Chapati, bread, cooking
Bakery industry	15	Bread, biscuits, cakes
Food processing	10	Noodles, pasta, snacks
Export	3	Flour exports to Afghanistan, others
Industrial uses	2	Starch, gluten extraction

9.3.5 Market Dynamics and Pricing

Domestic consumption:

- **Per capita consumption**: 115 kg annually (world's highest)
- **Total demand**: 27.5 million tons annually
- **Growth rate**: 2.5% annually following population growth
- **Regional variations**: Higher consumption in rural areas

Price structure and margins:

- **Wheat procurement price**: PKR 3,900/40kg (government support price)
- **Mill gate price**: PKR 4,200-4,500/40kg flour
- **Wholesale price**: PKR 4,300-4,600/40kg
- **Retail price**: PKR 4,500-4,800/40kg
- **Processing margin**: PKR 200-300/40kg (5-7%)

Government intervention:

- **Wheat procurement**: 4-6 million tons annually at support prices
- **Strategic reserves**: 3-4 million tons maintained
- **Subsidy mechanism**: Utility stores and targeted distribution
- **Price monitoring**: Regular market surveillance

9.3.6 Export Performance and International Trade

Export trends:

- **Volume**: 0.8-1.2 million tons annually (highly variable)
- **Value**: $180-250 million depending on volumes
- **Destinations**: Afghanistan (60%), Sri Lanka (15%), Others (25%)
- **Product mix**: Wheat flour (85%), wheat grain (15%)

Import dependency:

- **Occasional imports**: During production shortfalls (0.5-2.0 million tons)
- **Import sources**: Russia, Ukraine, Australia, Canada
- **Quality specifications**: Food-grade wheat with specific protein content
- **Strategic considerations**: Food security and price stabilization

Trade challenges:

- **Quality standards**: Meeting international food safety requirements
- **Competition**: Regional competitors with lower costs
- **Transportation**: High logistics costs to distant markets
- **Currency fluctuations**: Impact on export competitiveness

3.7 Technology and Modernization

Processing technology trends:

- **Automation**: Increasing adoption of automated milling systems
- **Energy efficiency**: Modern mills consume 35-45 kWh/ton vs. 65-80 kWh/ton in old mills
- **Quality control**: Laboratory testing and online monitoring systems
- **Packaging**: Modern packaging systems for consumer products

Innovation areas:

- **Fortification**: Iron, zinc, and vitamin fortification programs
- **Specialty flours**: Organic, gluten-free, and protein-enhanced products
- **By-product utilization**: Value addition from wheat bran and germ
- **Digital integration**: ERP systems and supply chain management

9.3.8 Challenges and Constraints

Raw material challenges:

- **Quality variability**: Inconsistent protein content and falling number
- **Storage losses**: Post-harvest losses due to poor storage facilities
- **Procurement issues**: Competition between mills and government agencies
- **Price volatility**: Fluctuating wheat prices are affecting margins

Operational challenges:

- **Energy costs**: High electricity and gas tariffs (25-30% of operating costs)
- **Competition**: Intense competition leading to thin margins
- **Capacity utilization**: Many mills are operating below optimal capacity
- **Working capital**: High inventory costs and delayed payments

Regulatory challenges:

- **Food safety standards**: Compliance with national and international standards
- **Environmental regulations**: Waste management and emission controls
- **Tax structure**: Multiple taxation affects competitiveness
- **Labor regulations**: Compliance with labor laws and social security

9.3.9 Development Strategies and Future Prospects

Modernization initiatives:

- **Technology upgradation**: Financing schemes for modern equipment
- **Capacity optimization**: Consolidation and efficiency improvements
- **Quality enhancement**: Focus on food safety and nutrition
- **Value addition**: Development of specialty and fortified products

Market development:

- **Export promotion**: Exploring new international markets
- **Branding**: Development of branded flour products
- **Distribution networks**: Strengthening supply chains
- **Consumer awareness**: Promoting nutritional benefits

Policy support required:

- **Energy subsidies**: Reduced energy costs for competitive operations

- **Quality standards**: Harmonized standards and certification systems
- **Export facilitation**: Streamlined procedures and incentives
- **Research support**: Technology development and transfer

9.4. Rice Industry

9.4.1 Industry Overview and Economic Significance

Pakistan's rice industry is a cornerstone of the country's agro-based economy, processing one of the most important export crops and contributing significantly to foreign exchange earnings. The industry encompasses rice production, processing, milling, and value-added product manufacturing, serving both domestic and international markets.

Economic importance:

- **Export value**: $2.3-2.8 billion annually (15% of total exports)
- **Processing volume**: 7.5-8.5 million tons of paddy annually
- **Employment**: 2.5 million people directly and indirectly
- **Foreign exchange**: Second-largest agricultural export after cotton/textiles
- **Rural livelihoods**: Support 1.8 million farming households

Global market position: Pakistan is the world's 4th largest rice exporter, specializing in Basmati and IRRI rice varieties. The country enjoys a premium position in the international Basmati rice market, competing primarily with India, and holds a significant market share in the non-Basmati rice segment.

9.4.2 Raw Material Base - Rice Production

Production overview: Rice cultivation in Pakistan covers approximately 3.2-3.5 million hectares annually, concentrated in Punjab (60%) and Sindh (38%), with smaller areas in Khyber Pakhtunkhwa and Balochistan.

Production statistics (2023-24):

- **Total area**: 3.3 million hectares
- **Total production**: 9.2 million tons (paddy)
- **Average yield**: 2.79 tons/hectare
- **Basmati production**: 2.8 million tons (30%)
- **IRRI production**: 6.4 million tons (70%)

Regional production distribution:

Region	Area (000 ha)	Production (000 tons)	Yield (tons/ha)
Punjab	2,000	5,750	2.88
Sindh	1,250	3,300	2.64
KP	45	125	2.78
Balochistan	5	25	5.00
Total	**3,300**	**9,200**	**2.79**

Rice varieties:

- **Basmati varieties**: Super Basmati, Basmati 385, Basmati 198, PK 1509
- **IRRI varieties**: IRRI-6, IRRI-9, KS-282, Shua-92
- **Hybrid varieties**: Guard-1, Pukhraj-1 (limited adoption)
- **Specialty varieties**: Brown rice, organic varieties (emerging)

9.4.3 Industry Structure and Processing

Rice milling industry structure: The rice processing industry consists of different categories of mills based on capacity, technology, and market focus.

Large-scale modern mills (capacity >50 tons/day):

- **Number**: 320 mills
- **Processing capacity**: 18,000 tons/day
- **Technology**: Modern parboiling, milling, and sorting equipment
- **Market focus**: Export-oriented production
- **Geographic concentration**: Punjab and Sindh rice-growing areas

Medium-scale mills (capacity 10-50 tons/day):

- **Number**: 850 mills
- **Processing capacity**: 12,000 tons/day
- **Technology**: Semi-modern equipment
- **Market focus**: Domestic and limited export
- **Distribution**: District-level centers

Small-scale mills (capacity <10 tons/day):

- **Number**: 2,500+ mills
- **Processing capacity**: 8,000 tons/day
- **Technology**: Traditional husking and polishing
- **Market focus**: Local domestic consumption
- **Coverage**: Rural and small urban centers

Processing technologies:

- **Modern integrated mills**: Complete processing line from paddy to packaged rice
- **Parboiling units**: Steam treatment for IRRI rice processing
- **Color sorting**: Advanced optical sorting for premium quality
- **Length grading**: Separation of broken rice from whole kernels

9.4.4 Product Portfolio and Quality Standards

Primary rice products:

- **White rice**: Fully milled rice for domestic consumption and export
- **Parboiled rice**: Steam-treated rice with enhanced nutritional value
- **Brown rice**: Partially milled rice retaining the bran layer
- **Broken rice**: Various grades are used for different applications

Quality classifications:

Basmati rice grades:

- **Super quality**: >6.5mm length, <7% broken
- **Grade-1**: 6.0-6.5mm length, <10% broken
- **Grade-2**: 5.5-6.0mm length, <15% broken
- **Lower grades**: Shorter length and higher broken percentage

IRRI rice grades:

- **Premium**: <5% broken, uniform kernels
- **Grade-A**: 5-10% broken
- **Grade-B**: 10-20% broken
- **Grade-C**: 20-35% broken

By-products and utilization:

By-product	Percentage	Primary Uses
Rice husk	20-22%	Fuel, building material, silica extraction
Rice bran	8-10%	Oil extraction, animal feed
Broken rice	15-20%	Animal feed, brewing, starch production
Polish/dust	2-3%	Animal feed supplement

9.4.5 Domestic and Export Markets

Domestic consumption:

- **Total domestic demand**: 3.2 million tons (milled rice)
- **Per capita consumption**: 13-15 kg annually
- **Regional preferences**: Basmati in urban areas, IRRI in rural areas
- **Growth rate**: 2-3% annually

Export performance:

- **Total exports**: 4.5-5.2 million tons annually
- **Export value**: $2.3-2.8 billion
- **Basmati exports**: 0.65-0.75 million tons ($800-900 million)
- **Non-Basmati exports**: 3.8-4.5 million tons ($1.5-1.9 billion)

Major export destinations:

Basmati rice markets:

Country	Share (%)	Volume (000 tons)
Saudi Arabia	22	165
UAE	18	135
UK	12	90
USA	10	75
Kuwait	8	60
Others	30	225

IRRI rice markets:

Country	Share (%)	Volume (000 tons)
China	25	1,000
Kenya	15	600
Madagascar	12	480
Philippines	10	400
UAE	8	320
Others	30	1,200

9.4.6 Value Addition and Processing Innovation

Value-added products:

- **Flavored rice**: Saffron, biryani, and other specialty preparations
- **Quick-cooking rice**: Pre-cooked and dried rice products
- **Rice-based snacks**: Crackers, crisps, and puffed rice products
- **Organic rice**: Certified organic production for premium markets
- **Fortified rice**: Nutrient-enhanced rice for nutrition programs

Processing innovations:

- **Minimal processing**: Retaining nutritional value
- **Modified atmosphere packaging**: Extended shelf life
- **Traceability systems**: Quality assurance and brand protection
- **Precision milling**: Optimized milling for specific end uses

By-product utilization:

- **Rice bran oil**: 15,000-20,000 tons annually
- **Rice husk power generation**: 50-100 MW potential
- **Silica extraction**: High-value industrial applications
- **Animal feed formulations**: Balanced feed products

9.4.7 Quality Control and Certification

Quality standards:

- **Pakistan Standards and Quality Control Authority (PSQCA)**: National standards
- **Export quality specifications**: Moisture content, broken percentage, foreign matter
- **International certifications**: ISO, HACCP, BRC, SQF standards
- **Organic certifications**: EU, USDA organic standards

Testing and monitoring:

- **Physical parameters**: Length, width, thickness, color
- **Chemical analysis**: Moisture, protein, amylose content
- **Microbial testing**: Pathogens and contamination
- **Pesticide residue**: Maximum residue limits (MRL) compliance

Traceability systems:

- **Seed-to-shelf tracking**: Complete supply chain monitoring
- **GPS mapping**: Field location recording
- **Batch coding**: Product identification and recall systems
- **Third-party verification**: Independent quality assurance

9.4.8 Major Challenges and Constraints

Production challenges:

- **Yield stagnation**: Average yields lower than potential
- **Quality deterioration**: Post-harvest handling issues
- **Water scarcity**: Increasing competition for irrigation water
- **Climate variability**: Extreme weather affecting crop quality

Processing challenges:

- **Energy costs**: High electricity and gas costs (20-25% of operating costs)
- **Technology gaps**: Need for modernization in many mills
- **Quality consistency**: Maintaining uniform quality standards
- **Capacity utilization**: Seasonal nature causing under-utilization

Market challenges:

- **International competition**: Strong competition from India, Thailand, and Vietnam
- **Price volatility**: Fluctuating international rice prices
- **Trade barriers**: Tariffs and non-tariff barriers in importing countries
- **Quality requirements**: Increasingly stringent quality standards

Infrastructure constraints:

- **Storage facilities**: Inadequate post-harvest storage
- **Transportation**: High logistics costs to ports
- **Port handling**: Congestion and delays at Karachi port
- **Laboratory facilities**: Limited testing infrastructure

9.4.9 Government Support and Policies

Policy framework:

- **Rice Export Policy**: Export promotion and quality enhancement
- **Minimum support prices**: Price support for farmers
- **Research and development**: Variety development and extension
- **Quality infrastructure**: Testing laboratories and certification

Export promotion:

- **Rice Exporters Association of Pakistan (REAP)**: Industry representation
- **Trade Development Authority of Pakistan**: Market promotion
- **Export financing**: Concessional credit facilities
- **Quality promotion**: Branding and marketing support

Regulatory framework:

- **Food safety regulations**: Compliance with international standards
- **Export licensing**: Registration and monitoring of exporters
- **Quality control**: Mandatory testing and certification
- **Phytosanitary requirements**: Plant health certificates

9.4.10 Future Prospects and Development Strategy

Growth opportunities:

- **Premium market development**: Focus on high-value Basmati segments
- **New market penetration**: Expanding to new geographical markets
- **Value-added products**: Processing for ready-to-eat and convenience foods
- **Organic production**: Developing certified organic rice value chains

Strategic priorities:

- **Productivity enhancement**: Improving yields through better varieties and practices
- **Quality improvement**: Upgrading processing facilities and standards
- **Market diversification**: Reducing dependence on traditional markets
- **Sustainability**: Adopting climate-smart and resource-efficient practices

Investment requirements:

- **Modernization**: $500 million for mill upgrades over 5 years
- **Storage infrastructure**: 2 million tons of additional storage capacity
- **Quality infrastructure**: Testing laboratories and certification facilities
- **Research and development**: Enhanced R&D capabilities

Target achievements by 2030:

- **Export value**: $4.0 billion (43% increase)
- **Productivity**: 4.0 tons/hectare average yield
- **Value addition**: 25% of exports in value-added products
- **Quality standards**: 90% of exports meet premium quality standards

9.5 Sugar Industry

9.5.1 Industry Overview and Economic Significance

Pakistan's sugar industry is one of the largest agro-based industries, processing sugarcane into sugar and various by-products. The industry plays a crucial role in the rural economy, providing direct employment to hundreds of thousands and supporting millions of sugarcane farmers across the country.

Economic importance:

- **Industry value**: PKR 800-900 billion annually
- **Production**: 6.0-7.5 million tons of sugar annually

- **Employment**: 0.5 million direct, 2.5 million indirect jobs
- **Farmer support**: 1.2 million sugarcane farming families
- **Industrial contribution**: 0.7% of GDP, 4.5% of the manufacturing sector

Global context: Pakistan ranks among the world's top 10 sugar producers, with production ranging from 6-7.5 million tons annually. The country has transitioned from sugar importer to occasional exporter, achieving self-sufficiency and building strategic reserves.

9.5.2 Raw Material Base - Sugarcane Production

Sugarcane cultivation: Sugarcane is grown on approximately 1.2-1.3 million hectares annually, primarily in Punjab (60%) and Sindh (35%), with smaller areas in Khyber Pakhtunkhwa and Balochistan.

Production statistics (2023-24):

- **Total area**: 1.28 million hectares
- **Total production**: 81.2 million tons
- **Average yield**: 63.4 tons/hectare
- **Sucrose recovery**: 9.8-10.5% (varies by region and season)
- **Crushing period**: November to April (5-6 months)

Provincial production distribution:

Province	Area (000 ha)	Production (000 tons)	Yield (tons/ha)
Punjab	750	48,500	64.7
Sindh	450	28,800	64.0
KP	75	3,600	48.0
Balochistan	5	300	60.0
Total	**1,280**	**81,200**	**63.4**

Sugarcane varieties:

- **Early maturing**: CP-77-400, SPF-213, HSF-240
- **Mid-season**: CP-72-2086, CP-43-33, Thatta-10
- **Late maturing**: CP-65-357, Mardan-93, S-2003-US-114

- **High sucrose varieties**: CPF-246, CPF-247, CPF-248

9.5.3 Industry Structure and Processing Capacity

Sugar mill classification: The sugar industry consists of sugar mills with varying capacities, technologies, and operational efficiencies.

Large-scale mills (capacity >10,000 TCD):

- **Number**: 28 mills
- **Total capacity**: 420,000 tons of cane per day (TCD)
- **Technology**: Modern extraction and processing equipment
- **Recovery rates**: 10.0-11.5%
- **Geographic distribution**: Punjab and Sindh

Medium-scale mills (capacity 5,000-10,000 TCD):

- **Number**: 45 mills
- **Total capacity**: 315,000 TCD
- **Technology**: Semi-modern equipment
- **Recovery rates**: 9.5-10.5%
- **Distribution**: Major cane-growing districts

Small-scale mills (capacity <5,000 TCD):

- **Number**: 12 mills
- **Total capacity**: 45,000 TCD
- **Technology**: Conventional processing
- **Recovery rates**: 9.0-10.0%
- **Coverage**: Smaller cane-growing areas

Total industry capacity: 780,000 TCD (can process 85-90 million tons annually)

Processing technology levels:

- **Modern mills**: 35% with advanced automation and energy recovery
- **Semi-modern mills**: 45% with partial automation
- **Conventional mills**: 20% with basic processing technology

9.5.4 Product Portfolio and By-products

Primary products:

- **White refined sugar**: 99.8% purity for domestic consumption
- **Raw sugar**: For export and industrial use
- **Plantation white**: Medium-quality sugar for local markets
- **Brown sugar**: Unrefined sugar with molasses content

By-products and utilization:

By-product	Quantity (per ton cane)	Primary Uses	Value (PKR/ton)
Molasses	35-45 kg	Ethanol, animal feed, yeast	15,000-20,000
Bagasse	280-320 kg	Fuel, paper, building material	3,000-5,000
Filter mud	15-25 kg	Fertilizer, soil conditioner	8,000-12,000
Cane trash	50-80 kg	Fuel, mulch, fodder	2,000-3,000

Value-added products:

- **Ethanol**: 160-200 million liters potential from molasses
- **Paper and pulp**: Bagasse-based paper production
- **Particle boards**: Building materials from bagasse
- **Organic fertilizers**: Composted filter mud and trash

9.5.5 Market Dynamics and Consumption

Domestic consumption:

- **Total consumption**: 6.2-6.8 million tons annually
- **Per capita consumption**: 25-27 kg annually
- **Growth rate**: 3-4% annually
- **Consumption pattern**: 60% household, 25% industrial, 15% institutional

Price structure:

- **Sugarcane price**: PKR 300-350 per 40kg (government-fixed minimum)
- **Ex-mill sugar price**: PKR 95-120 per kg
- **Wholesale price**: PKR 100-125 per kg

- **Retail price**: PKR 110-140 per kg
- **Processing margin**: PKR 15-25 per kg

Market supply and demand balance:

- **Production**: 6.0-7.5 million tons (varies annually)
- **Consumption**: 6.2-6.8 million tons
- **Strategic reserves**: 0.3-0.5 million tons
- **Export potential**: 0.5-1.5 million tons (in surplus years)
- **Import requirement**: 0.2-0.8 million tons (in deficit years)

9.5.6 Export Performance and Trade

Export trends:

- **Export volume**: 0.2-1.8 million tons annually (highly variable)
- **Export value**: $150-900 million, depending on volumes
- **Product mix**: Raw sugar (70%), white sugar (30%)
- **Destinations**: Afghanistan (40%), Sri Lanka (20%), Others (40%)

Import patterns:

- **Import volume**: 0.1-1.2 million tons (counter-cyclical to production)
- **Import sources**: Brazil (40%), Thailand (25%), India (20%), Others (15%)
- **Import timing**: During domestic shortfalls
- **Quality**: Raw sugar for refining

Trade challenges:

- **International price volatility**: Global sugar prices highly volatile
- **Quality standards**: Meeting international specifications
- **Logistics costs**: High transportation costs to ports
- **Competition**: Brazil, Thailand, and India are dominating global trade

9.5.7 Technology and Modernization

Processing technology improvements:

- **Extraction efficiency**: Modern mills achieve 96-98% extraction
- **Energy optimization**: Bagasse-based cogeneration systems

- **Automation**: Process control and monitoring systems
- **Quality enhancement**: Advanced clarification and crystallization

Cogeneration and energy:

- **Power generation**: 300-400 MW installed cogeneration capacity
- **Energy surplus**: 150-200 MW potential for grid supply
- **Steam efficiency**: Modern boilers achieve 85-90% efficiency
- **Environmental benefits**: Reduced fossil fuel dependence

Research and development:

- **Pakistan Sugar Mills Association (PSMA)**: Industry research coordination
- **Sugar Research Institute**: Varietal development and processing research
- **International collaboration**: Technology transfer partnerships
- **Innovation focus**: Process efficiency and product diversification

9.5.8 Major Challenges and Issues

Raw material challenges:

- **Yield variability**: Weather-dependent cane production
- **Sucrose content**: Low recovery rates compared to international standards
- **Quality deterioration**: Post-harvest handling and transportation delays
- **Water scarcity**: Increasing irrigation constraints

Operational challenges:

- **Seasonal operation**: Mills operate only 5-6 months annually
- **Capacity utilization**: Many mills are operating below optimal capacity
- **Energy costs**: High fuel costs for non-cogeneration mills
- **Working capital**: Delayed payments and high interest rates

Market and pricing issues:

- **Price controls**: Government intervention in pricing mechanisms
- **Circular debt**: Payment delays throughout the value chain
- **Competition**: Imported sugar during surplus periods
- **Smuggling**: Cross-border smuggling affecting domestic markets

Structural issues:

- **Technology gaps**: Need for modernization in older mills
- **Scale inefficiencies**: Small mills with higher per-unit costs
- **Integration**: Limited forward and backward integration
- **Governance**: Weak industry coordination and planning

9.5.9 Government Policies and Support

Policy framework:

- **Sugar Policy**: Comprehensive industry development strategy
- **Price support**: Minimum sugarcane prices for farmers
- **Export policies**: Export permits and incentives
- **Import regulations**: Tariff structure and quality standards

Regulatory institutions:

- **Sugar Advisory Board**: Policy formulation and monitoring
- **Competition Commission**: Market regulation and fair practices
- **Trading Corporation of Pakistan**: Strategic trading operations
- **Provincial Cane Commissioners**: Regional coordination and dispute resolution

Support measures:

- **Research support**: Funding for varietal development and extension
- **Technology upgradation**: Concessional financing for modernization
- **Infrastructure development**: Rural roads and transportation facilities
- **Export facilitation**: Simplified procedures and financing support

9.5.10 Future Prospects and Development Strategy

Growth opportunities:

- **By-product development**: Ethanol production and industrial applications
- **Export potential**: Leveraging surplus production in good years
- **Value addition**: Specialty sugars and refined products
- **Regional integration**: Trade opportunities with neighboring countries

Strategic priorities:

- **Productivity enhancement**: Improving cane yields and sugar recovery
- **Technology modernization**: Upgrading processing capabilities
- **Diversification**: Developing by-product industries
- **Sustainability**: Adopting environmentally friendly practices

Investment requirements:

- **Mill modernization**: $1.5 billion over the next 5 years
- **Cogeneration expansion**: $800 million for power projects
- **Research facilities**: Enhanced R&D infrastructure
- **Value chain integration**: $500 million for by-product industries

Development targets by 2030:

- **Production capacity**: 9-10 million tons of sugar annually
- **Recovery rates**: Average 11.5% sugar recovery
- **Energy generation**: 800-1000 MW cogeneration capacity
- **Export potential**: 2-3 million tons in surplus years

9.6 Maize Processing Industry

9.6.1 Industry Overview and Significance

Pakistan's maize processing industry has emerged as an important agro-based sector, transforming maize grain into various food, feed, and industrial products. While historically focused on animal feed production, the industry is diversifying into high-value products, including starch, glucose, and processed food items.

Economic importance:

- **Processing volume**: 4.5-5.5 million tons annually (60-70% of production)
- **Industry value**: PKR 300-400 billion
- **Employment**: 150,000 direct jobs, 500,000 indirect
- **Growth rate**: 8-12% annually (fastest growing grain processing sector)
- **Export potential**: $50-80 million annually in processed products

Market evolution: The industry has evolved from simple crushing and feed manufacturing to sophisticated processing operations producing starch, sweeteners, alcohol, and specialty food products for domestic and export markets.

9.6.2 Raw Material Base - Maize Production

Maize production overview: Maize cultivation has expanded rapidly in Pakistan, becoming the third-largest cereal crop after wheat and rice. The crop is grown in both spring (February-July) and autumn (August-December) seasons.

Production statistics (2023-24):

- **Total area**: 1.4 million hectares
- **Total production**: 8.9 million tons
- **Average yield**: 6.36 tons/hectare
- **Spring maize**: 55% of total production
- **Autumn maize**: 45% of total production

Provincial distribution:

Province	Area (000 ha)	Production (000 tons)	Yield (tons/ha)
Punjab	1,150	7,200	6.26
KP	210	1,450	6.90
Sindh	35	220	6.29
Balochistan	5	30	6.00
Total	**1,400**	**8,900**	**6.36**

Maize varieties and types:

- **Hybrid varieties**: Monsanto DK-6142, Pioneer 30Y87 (85% of production)
- **Composite varieties**: Sarhad White, Azam, Jalal (15% of production)
- **Specialty types**: High-lysine, waxy, and popping corn (emerging)
- **Quality parameters**: Moisture 14-16%, protein 8-12%, oil 3-5%

9.6.3 Industry Structure and Processing Categories

Feed manufacturing (70% of processing):

- **Large-scale mills**: 85 mills with capacity >200 tons/day
- **Medium-scale mills**: 350 mills with a capacity of 50-200 tons/day
- **Small-scale mills**: 2,500+ mills with capacity <50 tons/day

- **Total capacity**: 180,000 tons/day (65 million tons annually)

Starch and glucose industry (15% of processing):

- **Large integrated units**: 12 facilities
- **Processing capacity**: 2,800 tons/day maize equivalent
- **Products**: Native starch, modified starch, glucose syrup, dextrose
- **Technology levels**: Modern enzymatic and acid hydrolysis processes

Food processing (10% of processing):

- **Breakfast cereals**: 8 major manufacturers
- **Snack foods**: 45+ manufacturers of various sizes
- **Flour and meal**: 200+ mills producing maize flour
- **Traditional products**: Makka atta, corn meal for household use

Industrial processing (5% of processing):

- **Ethanol production**: 3 distilleries with maize feedstock
- **Paper and packaging**: Corn starch for adhesives
- **Textile sizing**: Starch for textile applications
- **Pharmaceutical**: Excipients and carriers

9.6.4 Product Portfolio and Applications

Animal feed products:

- **Poultry feed**: 65% of maize feed consumption
- **Cattle feed**: 25% of consumption
- **Aqua feed**: 8% (rapidly growing segment)
- **Pet food**: 2% (premium segment)

Industrial starch products:

- **Native corn starch**: 45,000 tons annually
- **Modified starches**: 15,000 tons (pharmaceutical, food, industrial)
- **Glucose syrup**: 25,000 tons (food and beverage industry)
- **High fructose corn syrup**: 8,000 tons (emerging market)
- **Dextrose**: 12,000 tons (pharmaceutical and food applications)

Food products:

- **Corn flour**: 180,000 tons annually
- **Cornflakes and cereals**: 25,000 tons
- **Snack foods**: 120,000 tons (chips, puffs, extruded products)
- **Traditional foods**: Corn meal, polenta, tortilla base

By-products:

By-product	Quantity (% of grain)	Applications	Value (PKR/ton)
Corn gluten meal	6-8%	High-protein animal feed	85,000-95,000
Corn gluten feed	18-22%	Dairy cattle feed	35,000-45,000
Corn germ meal	8-12%	Animal feed, oil extraction	40,000-50,000
Corn bran	12-15%	Animal feed, fiber source	25,000-35,000

9.6.5 Technology and Processing Methods

Dry milling processes:

- **Conventional milling**: Hammer mills and roller mills
- **Degerming**: Separation of germ for oil extraction
- **Sifting and grading**: Size separation for different products
- **Quality control**: Moisture, protein, and mycotoxin testing

Wet milling (starch production):

- **Steeping**: Corn soaking in dilute sulfur dioxide
- **Coarse grinding**: Breaking kernels and separating components
- **Germ separation**: Oil recovery from germs
- **Fine grinding and screening**: Starch and protein separation
- **Starch purification**: Washing and concentration

Fermentation processes:

- **Ethanol production**: Enzymatic conversion and distillation

- **Organic acids**: Citric acid, lactic acid production
- **Amino acids**: Lysine and other amino acid fermentation
- **Antibiotics**: Corn steep liquor as fermentation medium

9.6.6 Market Dynamics and Demand

Domestic consumption patterns:

- **Animal feed**: 4.2 million tons (78% of processed maize)
- **Food products**: 0.8 million tons (15%)
- **Industrial uses**: 0.25 million tons (5%)
- **Seed and wastage**: 0.12 million tons (2%)

9.7 Self-Assessment Questions

Fill the blanks

1. The agro-industrial sector contributes approximately _____ to Pakistan's total manufacturing output.
2. _____represents the largest and most important agro-based industry in Pakistan,
3. Total area under cultivation of wheat was _____ during 2023-24.
4. _____ province of Pakistan is the largest producer of rice
5. Garde-1 rice contains less than _____percent broken grains

Answers

1) 68.0% 2) The cotton and textile industry 3) 9.0 million hectares 4) Punjab 5) 10

9.8 References

1. Government of Pakistan. (2024). *Agricultural Statistics of Pakistan 2023-24*. Ministry of National Food Security & Research, Islamabad.
2. Pakistan Bureau of Statistics (PBS). (2023). *Pakistan Statistical Year Book 2023*. Islamabad.
3. State Bank of Pakistan. (2023). *Annual Report 2022–23: The State of Pakistan's Economy*. Karachi.
4. All Pakistan Textile Mills Association (APTMA). (2023). *Textile Industry Review 2022–23*. Lahore.
5. Pakistan Sugar Mills Association (PSMA). (2023). *Annual Review of Sugar Industry in Pakistan*. Islamabad.
6. Rafhan Maize Products Co. Ltd. (2023). *Annual Report 2022–23*. Faisalabad, Pakistan.
7. Hussain, M., Ali, A., & Khan, M. A. (2022). "Maize Production and Utilization Trends in Pakistan: Challenges and Opportunities." *Pakistan Journal of Agricultural Sciences*, 59(3), 411–420.
8. Malik, S. J., & Nazli, H. (2021). "Agro-based Industrial Development in Pakistan: Value Chain and Policy Options." *Pakistan Institute of Development Economics (PIDE) Working Paper Series*, Islamabad.
9. Food and Agriculture Organization of the United Nations (FAO). (2021). *Agro-Industry Outlook in South Asia*. Rome.
10. International Maize and Wheat Improvement Center (CIMMYT). (2022). *Maize in Pakistan: Current Situation and Future Outlook*. Mexico City.
11. United States Department of Agriculture (USDA). (2023). *Grain and Feed Annual: Pakistan*. Foreign Agricultural Service (FAS).
12. Yousaf, H., & Ashfaq, M. (2020). "Adoption of Hybrid Maize Seed in Pakistan and Its Impact on Productivity." *Sarhad Journal of Agriculture*, 36(4), 1087–1095.
13. Shakarganj Foods Ltd. (2023). *Corporate Profile and Product Portfolio*. Jhang, Pakistan.