Chapter 2

Theoretical Orientation

This chapter is devoted to the development of theoretical orientation for the study. Theoretical orientation provides the rationale for ideas. Toulin (1974) stated that theoretical ideas of a science are not something separate and apart from ideas in general, for example, the idea that guides practice in technology, policies and other areas of extra scientific life. This would reduce the chances of misconception.

Global warming

Global warming refers to an unequivocal and continuing rise in the average temperature of Earth's climate system. Since 1971, 90% of the warming has occurred in the oceans. Despite the oceans' dominant role in energy storage, the term global warming is also used to refer to increases in average temperature of the air and sea at Earth's surface. Since the early 20th century, the global air and sea surface temperature has increased about 0.8 °C (1.4 °F), with about two-thirds of the increase occurring since 1980. Each of the last three decades has been

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successively warmer at the Earth's surface than any preceding decade since 1850.

Global warming became more widely popular after 1988 when NASA climate scientist James Hansen used the term in a testimony to Congress. He said: "global warming has reached a level such that we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect and the observed warming." His testimony was widely reported and afterward global warming was commonly used by the press and in public discourse.

Future climate change and associated impacts will vary from region around the globe. The effects of an increase in global temperature include a rise in sea levels and a change in the amount and pattern of precipitation, as well as a probable expansion of subtropical deserts. Warming is expected to be strongest in the Arctic, with the continuing retreat, permafrost and sea ice. Other likely effects of the warming include more frequent extreme weather events including heat waves, droughts and heavy rainfall; ocean acidification; and species extinctions due to shifting temperature regimes. Effects significant to humans include the threat to food security from decreasing crop yields and the habitat from inundation.

Scientific understanding of the cause of global warming has been increasing. In its fourth assessment of the relevant scientific literature, the International (IPCC) reported that scientists were more than 90% certain that most of global warming was being

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caused by increasing concentrations of greenhouse gases produced by human activities. In 2010 that finding was recognized by the national science academies of all major industrialized nations. Affirming these findings in 2013, the IPCC stated that the largest driver of global warming is carbon dioxide (CO_2) emissions from fossil fuel combustion, cement production, and land changes such as deforestation. Its 2013 report Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since AR4. It is extremely likely (95-100%) that human influence has been the dominant cause of the observed warming since the mid-20th century.

—IPCC AR5 WG1 Summary for Policymakers

Contents of global warming

1) Observed temperature changes

The Earth's average surface temperature rose by 0.74±0.18 °C over the period 1906–2005. The rate of warming over the last half of that period was almost doubles that for the period as a whole (0.13±0.03 °C per decade, versus 0.07±0.02 °C per decade). The island effect is very small, estimated to account for less than 0.002 °C of warming per decade since 1900. Temperatures in the lower troposphere have increased between 0.13 and 0.22 °C (0.22 and 0.4 °F) per decade since 1979,

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according to measurements. Climate show the temperature to have been relatively stable over the one or two thousand years before 1850, with regionally varying fluctuations such as the Medieval Warm Period and the Little Ice Age.

The warming that is evident in the instrumental temperature record is consistent with a wide range of observations, as documented by many independent scientific groups. Examples include sea level rise (water expands as it warms), widespread melting of snow and ice, increased heat content of the oceans, increased humidity, and the earlier timing offspring events, e.g., temperature changes vary over the globe. Since 1979, land temperatures have increased about twice as fast as ocean temperatures (0.25 °C per decade against 0.13 °C per decade). Ocean temperatures increase more slowly than land temperatures because of the larger effective heat capacity of the oceans and because the ocean loses more heat by evaporation. The northern hemisphere is also naturally warmer than the southern hemisphere mainly because of meridional heat transport in the oceans which has a differential of about 0.9 pet watts northwards, with an additional contribution from the albedo differences between the Polar Regions. Since the beginning of industrialization the interhemispheric temperature difference has increased due to melting of sea ice and snow in the North. Average arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years; however arctic temperatures are also highly variable. Although

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more greenhouse gases are emitted in the Northern than Southern Hemisphere this does not contribute to the difference in warming because the major greenhouse gases persist long enough to mix between hemispheres.

The thermal inertia of the oceans and slow responses of other indirect effects mean that climate can take centuries or longer to adjust to changes in forcing. Climate commitment studies indicate that even if greenhouse gases were stabilized at 2000 levels, a further warming of about 0.5 °C (0.9 °F) would still occur.

2) Initial causes of temperature changes

The climate system can respond to changes in external forcing. External forcing can "push" the climate in the direction of warming or cooling. Examples of external forcing include changes in atmospheric composition (e.g., increased concentrations of greenhouse gases), solar luminosity, volcanic eruptions, and variations in Earth's orbit around the Sun. cycles vary slowly over tens of thousands of years and at present are in an overall cooling trend which would be expected to lead towards an ice age, but the 20th century instrumental temperature record shows a sudden rise in global temperatures.

2.1) Green house gases

The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in a planet's atmosphere warm its lower atmosphere and surface. It was proposed by

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Joseph in 1824, discovered in 1860 by John Tyndall, was first investigated quantitatively by Svante Arrhenius in 1896, and was developed in the 1930s through 1960s by Guy Stewart Callendar.

On earth, naturally occurring amounts of greenhouse gases have a mean warming effect of about 33 °C (59 °F). Without the Earth's atmosphere, the temperature across almost the entire surface of the Earth would be below freezing. The major greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect; carbon dioxide (CO_2), which causes 9–26%; methane (CH_4), which causes 4–9%; and ozone (O_3), which causes 3–7%. Clouds also affect the radiation balance through cloud forcing similar to greenhouse gases.

Over the last three decades of the 20th century, gross domestic product per capita and population growth were the main drivers of increases in greenhouse gas emissions. CO_2 emissions are continuing to rise due to the burning of fossil fuels and land-use change. Emissions can be attributed to different regions, e.g., see the figure opposite. Attribution of emissions due to land-use change is a controversial issue.

2.2) Particulates and soot

Global dimming, a gradual reduction in the amount of global direct irradiance at the Earth's surface, was observed from 1961 until at least 1990. The main cause of this dimming is particulates produced by volcanoes and human made pollutants, which exerts a cooling effect by increasing the reflection of incoming sunlight. The effects of the products of fossil fuel combustion – CO_2 and

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aerosols – have partially offset one another in recent decades, so that net warming has been due to the increase in non-CO_2 greenhouse gases such as methane. Radioactive forcing due to particulates is temporally limited due to wet deposition which causes them to have an atmospheric of one week. Carbon dioxide has a lifetime of a century or more, and as such, changes in particulate concentrations will only delay climate changes due to carbon dioxide. Black carbon is second only to carbon dioxide for its contribution to global warming. In addition to their direct effect by scattering and absorbing solar radiation, particulates have indirect effects on the Earth's radiation budget.

Soot may cool or warm the surface, depending on whether it is airborne or deposited. Atmospheric soot directly absorbs solar radiation, which heats the atmosphere and cools the surface. In isolated areas with high soot production, such as rural India, as much as 50% of surface warming due to greenhouse gases may be masked by atmospheric brown clouds.

2.3) Solar activity

Since 1978, output from the Sun has been precisely measured by satellites. These measurements indicate that the Sun's output has not increased since 1978, so the warming during the past 30 years cannot be attributed to an increase in solar energy reaching the Earth. Climate models have been used to examine the role of the sun in recent climate change. Models are unable to reproduce the rapid warming observed in recent decades when they only

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take into account variations in solar output and volcanic activity. Models are, however, able to simulate the observed 20th century changes in temperature when they include all of the most important external forcing, including human influences and natural forcing.

Another line of evidence against the sun having caused recent climate change comes from looking at how temperatures at different levels in the Earth's atmosphere have changed. Models and observations show that greenhouse warming results in warming of the lower atmosphere (called the troposphere) but cooling of the upper atmosphere (called the stratosphere). Depletion of the ozone layer by chemical refrigerants has also resulted in a strong cooling effect in the stratosphere.

3) Climate models

A climate model is a computerized representation of the five components of the climate system system: Atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Such models are based on scientific disciplines such as fluid dynamics, thermodynamics as well as physical processes such as radioactive. The models take into account various components, such as local air movement, temperature, clouds, and other atmospheric properties; ocean temperature, salt content, and circulation; ice cover on land and sea; the transfer of heat and moisture from soil and vegetation to the atmosphere; chemical and biological processes; solar variability and others. The models do not assume the climate will warm due to increasing levels of

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greenhouse gases. Instead the models predict how greenhouse gases will interact with radioactive transfer and other physical processes. One of the mathematical results of these complex equations is a prediction whether warming or cooling will occur.

4) Observed and expected environmental effects

"Detection" is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change. Detection does not imply attribution of the detected change to a particular cause. "Attribution" of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence. Detection and attribution may also be applied to observed changes in physical, ecological and social systems.

4.1) Natural system

Global warming has been detected in a number of natural systems. Some of these changes are described in the section on observed temperature changes, e.g., sea level rise and widespread decreases in snow and ice extent. Anthropogenic forcing has likely contributed to some of the observed changes, including sea level rise, changes in climate extremes (such as the number of warm and cold days), declines in Arctic sea ice extent, and to glacier retreat

Over the 21st century, the IPCC projects that global mean sea level could rise by 0.18-0.59 m. The IPCC do not provide a best estimate of global mean sea level rise, and their upper estimate

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of 59 cm is not an upper-bound, i.e., global mean sea level could rise by more than 59 cm by 2100. The IPCC's projections are conservative, and may underestimate future sea level rise. Over the 21st century, Parris and others suggest that global mean sea level could rise by 0.2 to 2.0 m (0.7-6.6 ft), relative to mean sea level in 1992.

Changes in regional climate are expected to include greater warming over land, with most warming at high northern latitudes, and least warming over the southern ocean and parts of the North Atlantic Ocean. During the 21st century, glacieiers and snow cover are projected to continue their widespread retreat. Projections of declines in Arctic sea ice vary. Recent projections suggest that Arctic summers could be ice-free (defined as ice extent less than 1 million square) as early as 2025-2030.

4.2) Ecological system

In terrestrial ecosystems, the earlier timing of spring events, and pole ward and upward shifts in plant and animal ranges, have been linked with high confidence to recent warming. Future climate change is expected to particularly affect certain ecosystems, including tundra, mangroves, and coral reefs. It is expected that most ecosystems will be affected by higher atmospheric CO_2 levels, combined with higher global temperatures. Overall, it is expected that climate change will result in the extinction of many species and reduced diversity of ecosystems.

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Increases in atmospheric CO_2 concentrations have led to an increase in ocean acidity. Dissolved CO_2 increases ocean acidity, which is measured by lower pH values. Between 1750 to 2000, surface-ocean pH has decreased by ~0.1, from ~8.2 to ~8.1. Surface-ocean pH has probably not been below ~8.1 during the past 2 million years. Projections suggest that surface-ocean pH could decrease by additional 0.3-0.4 units by 2100. Future ocean acidification could threaten coral reefs, fisheries, protected species, and other natural resources of value to society.

4.3) Long term effects

On the timescale of centuries to millennia, the magnitude of global warming will be determined primarily by anthropogenic CO_2emissions.This is due to carbon dioxide's very long lifetime in the atmosphere.

Stabilizing global average temperature would require reductions in anthropogenic CO_2 emissions. Reductions in emissions of non-CO_2 anthropogenic GHGs (e.g., methane and nitrous oxide) would also be necessary. For CO_2, anthropogenic emissions would need to be reduced by more than 80% relative to their peak level. Even if this were to be achieved, global average temperatures would remain close to their highest level for many centuries.

4.4) Large scale and abrupt impacts

Climate change could result in global, large-scale changes in natural and social systems. Two examples are acidification

ISBN: 978-93-85822-63-6

caused by increased atmospheric concentrations of carbon dioxide, and the long-term melting of ice sheets, which contributes to sea level rise.

Some large-scale changes could occur abruptly, i.e., over a short time period, and might also be irreversible. An example of abrupt climate change is the rapid release of methane and carbon dioxide from permafrost, which would lead to amplified global warming. Scientific understanding of abrupt climate change is generally poor. However, the probability of abrupt changes appears to be very low. Factors that may increase the probability of abrupt climate change include higher magnitudes of global warming, warming that occurs more rapidly, and warming that is sustained over longer time periods.

5) Observed and expected effects on social system

Vulnerability of human societies to climate change mainly lies in the effects of extreme weather events rather than gradual climate change. Impacts of climate change so far include adverse effects on small islands, adverse effects on indigenous populations in high-latitude areas, and small but discernable effects on human health. Over the 21st century, climate change is likely to adversely affect hundreds of millions of people through increased coastal flooding, reductions in water supplies, increased malnutrition and increased health impacts.

The economic impacts of climate change are highly uncertain. Small magnitudes of global warming (0 to 2 °C, relative to pre-industrial levels) could lead to losses or gains in world gross

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domestic product (GDP). Above around 2.5 °C, most studies suggest losses in world GDP, with greater losses at higher temperatures.

5.1) Food security

Under present trends, by 2030, maize production in Southern Africa could decrease by up to 30%, while rice, millet and maize in South Asia could decrease by up to 10%. By 2080, yields in developing countries could decrease by 10% to 25% on average while India could see a drop of 30% to 40%. By 2100, while the population of three billion is expected to double, rice and maize yields in the tropics are expected to decrease by 20–40% because of higher temperatures without accounting for the decrease in yields as a result of soil moisture and water supplies stressed by rising temperatures.

Future warming of around 3 °C (by 2100, relative to 1990–2000) could result in increased crop yields in mid- and high-latitude areas, but in low-latitude areas, yields could decline, increasing the risk of malnutrition. A similar regional pattern of net benefits and costs could occur for economic (market-sector) effects. Warming above 3 °C could result in crop yields falling in temperate regions, leading to a reduction in global food production.

5.2) Habitat inundation

In small islands and mega deltas, inundation as a result of sea level rise is expected to threaten vital infrastructure and human settlements. This could lead to issues of homelessness in countries with low lying areas such as Bangladesh, as well as statelessness for populations in countries such as the Maldives and Tuvalu.

6. Discourse about global warming

6.1) Scientific discussion

Most scientists agree that humans are contributing to observed climate change. A Meta study of academic papers concerning global warming, published between 1991 and 2011 and accessible from Web of Knowledge, found that among those whose abstracts expressed a position on the cause of global warming, 97.2% supported the consensus view that it is manmade. In an October 2011 paper published in the International Journal of Public Opinion Research, researchers from George Mason University analyzed the results of a survey of 489 American scientists working in academia, government, and industry. Of those surveyed, 97% agreed that that global temperatures have risen over the past century and 84% agreed that "human-induced greenhouse warming" is now occurring, only 5% disagreeing that human activity is a significant cause of global warming. National science academies have called on world leaders for policies to cut global emissions.

In the scientific literature, there is a strong consensus that global surface temperatures have increased in recent decades and that the trend is caused mainly by human-induced emissions

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of greenhouse gases. No scientific body of national or international standing disagrees with this view.

6.2) Discussion by the public and in popular media

The global warming controversy refers to a variety of disputes, substantially more pronounced in the popular media than in the scientific literature, regarding the nature, causes, and consequences of global warming. The disputed issues include the causes of increased global average air temperature, especially since the mid-20th century, whether this warming trend is unprecedented or within normal climatic variations, whether humankind has contributed significantly to it, and whether the increase is wholly or partially an artefact of poor measurements. Additional disputes concern estimates of climate sensitivity, predictions of additional warming, and what the consequences of global warming will be.

Some people dispute aspects of climate change science. Organizations such as the libertarian Competitive Enterprise Institute, conservative commentators, and some companies such as ExxonMobil have challenged IPCC climate change scenarios, funded scientists who disagree with the scientific consensus, and provided their own projections of the economic cost of stricter controls. Some fossil fuel companies have scaled back their efforts in recent years, or called for policies to reduce global warming.

ISBN: 978-93-85822-63-6

6.3) Surveys of public opinion

Researchers at the University of Michigan have found that the public's belief as to the causes of global warming depends on the wording choice used in the polls.

A March–May 2013 survey by Pew Research Center for the People & the Press polled 39 countries about global threats. According to 54% of those questioned, global warming featured top of the perceived global threats. In a January 2013 survey, Pew found that 69% of Americans say there is solid evidence that the Earth's average temperature has been getting warmer over the past few decades, up six points since November 2011 and 12 points since 2009.

Climate & weather

Climate

Climate is a measure of the average pattern of variation in temperature, humidity, pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate is different from weather, in that weather only describes the short-term conditions of these variables in a given region.

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World

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Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.

Weather

Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy. Most weather phenomena occur in the troposphere, just below the stratosphere. Weather generally refers to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time. When used without qualification, "weather", is understood to mean the weather of Earth.

Weather is driven by air pressure (temperature and moisture) differences between one place and another. These pressure and temperature differences can occur due to the sun angle at any particular spot, which varies by latitude from the tropics. The strong temperature contrast between polar and tropical air gives rise to the jet stream. Weather systems in the mid-latitudes, such as extra tropical cyclones, are caused by instabilities of the jet stream flow. Because the Earth's axis is tilted relative to its orbital plane, sunlight is incident at different angles at different

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times of the year. On Earth's surface, temperatures usually range ±40 °C (−40 °F to 100 °F) annually. Over thousands of years, changes in Earth's orbit affect the amount and distribution of solar energy received by the Earth and influence long-term climate and global climate change.

Climate risk manager

According to Prof. Swaminathan at least one women and one male member of every block/ Panchayat should be trained in as "Climate Risk Manager" in order to help the village to handle situation like drought flood and sea level rise in coastal region in an effective manner. Such climate risk managers should become well versed in the science and art of disaster management.

Establishment of seed, grain and water bank are essential to mitigate the risk on climate change. The seed bank should consist of locally adapted strains which can do well under late sown and unfavorable condition.

Community based weather forecasting

Traditionally farmers monitor rainfall and other weather parameter based on their indigenous knowledge on weather. These measurements usually gave an idea about rainfall patterns but farmers lacked exact quantification. Many farmers in semi-arid India have established their own weather observation systems using manual rain gauges, thermometers and wind anemometers to plan their farming activities. The local weather observations are interpreted by the farmers in combination with

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the localized weather and climate forecasts to take up appropriate farm decisions.

Climate change extension: concept

The extension approach and services that specifically address ecological repercussions, over exploitation of natural resources, potential problems arising from global warming and climate change, bringing mass awareness about harmful effect of climate change, motivating people to adopt mitigation practices through demonstration of climate coping technologies ; identification, documentation and validation of indigenous Traditional Knowledge (ITK) are climate change extension.

For this purpose the extension agent must acquire comprehensive knowledge and understanding of the science of global warming and climate change so that extension programmes can be oriented accordingly. (Sagar Mondal, 2013)

Climate change extension: World wide innovations

Climate field school in Thailand

Asian Disaster Preparedness Centre (ADPC), Bangkok has introduced the concept of "Climate Field Schools" to improve the basic knowledge of farmers on climate forecast used in designing crop management strategies. The concept of climate field schools follows the concept of farmers, based on their experiences.

The aim of climate field school is to familiarize participants to the process of learning by practice. Climate field schools are a continuous process involving discussions, sharing and analyzing

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experiences, drawing conclusions and taking action and finally acquiring renewed experiences from the actions taken.

All processes are facilitated by field facilitators such as extension workers and farmer leaders. The scientists of KVK's and line departments have to play a major role in this direction for effective preparedness and reducing risks.

Causes of climate change

(1) Internal forcing mechanisms

Natural changes in the components of Earth's climate system and their interactions are the cause of internal climate variability, or "internal forcing." Scientists generally define the five components of earth's climate system to include atmosphere, hydrosphere, cryosphere, lithosphere (restricted to the surface soils, rocks, and sediments), and biosphere.

(i) Ocean variability

The ocean is a fundamental part of the climate system, some changes in it occurring at longer timescales than in the atmosphere, massing hundreds of times more and having very high thermal inertia (such as the ocean depths still lagging today in temperature adjustment from the Little Ice Age.

Short-term fluctuations (years to a few decades) such as the El Niño-Southern Oscillation, the Pacific decadal oscillation, the North Atlantic oscillation, and the Arctic oscillation, represent climate variability rather than climate change. On longer time scales, alterations to ocean processes such as thermohaline

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circulation play a key role in redistributing heat by carrying out a very slow and extremely deep movement of water and the long-term redistribution of heat in the world's oceans.

(ii) Life

Life affects climate through its role in the carbon and water cycles and such mechanisms as albedo, evapotranspiration, cloud formation, and weathering Examples of how life may have affected past climate include: glaciations 2.3 billion years ago triggered by the evolution of oxygenic photosynthesis, glaciations 300 million years ago ushered in by long-term burial of resistant detritus of vascular land plants (forming coal), termination of the Paleocene-Eocene Thermal Maximum 55 million years ago by flourishing marine phytoplankton, reversal of global warming 49 million years ago by 800,000 years of arctic azolla blooms, and global cooling over the past 40 million years driven by the expansion of grass-grazer ecosystems.

(2) External forcing mechanisms

(i) Orbital variations

Slight variations in Earth's orbit lead to changes in the seasonal distribution of sunlight reaching the Earth's surface and how it is distributed across the globe. There is very little change to the area-averaged annually averaged sunshine; but there can be strong changes in the geographical and seasonal distribution. The three types of orbital variations are variations in Earth's eccentricity, changes in the tilt angle of Earth's axis of rotation,

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and precession of Earth's axis. Combined together, these produce Milankovitch cycles which have a large impact on climate and are notable for their correlation to glacial and interglacial periods, their correlation with the advance and retreat of the Sahara, and for their appearance in the stratographic.

The IPCC notes that Milankovitch cycles drove the ice age cycles, CO_2 followed temperature change "with a lag of some hundreds of years," and that as a feedback amplified temperature change. The depths of the ocean have a lag time in changing temperature (thermal inertia on such scale). Upon seawater temperature change, the solubility of CO_2 in the oceans changed, as well as other factors impacting air-sea CO_2 exchange.

(ii) Solar output

The Sun is the predominant source for energy input to the Earth. Both long- and short-term variations in solar intensity are known to affect global climate.

Three to four billion years ago the sun emitted only 70% as much power as it does today. If the atmospheric composition had been the same as today, liquid water should not have existed on Earth. However, there is evidence for the presence of water on the early Earth, in the Hadean and Archean eons, leading to what is known as the paradox. Hypothesized solutions to this paradox include a vastly different atmosphere, with much higher concentrations of greenhouse gases than currently exist. Over the following approximately 4 billion years, the energy output of the sun increased and atmospheric composition changed. The Great

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Oxygenation Event – oxygenation of the atmosphere around 2.4 billion years ago – was the most notable alteration. Over the next five billion years the sun's ultimate death as it becomes a red giant and then a white dwarf will have large effects on climate, with the red giant phase possibly ending any life on Earth that survives until that time.

In an Aug 2011 Press Release, CERN announced the publication in the Nature journal the initial results from its CLOUD experiment. The results indicate that ionisation from cosmic rays significantly enhances aerosol formation in the presence of sulphuric acid and water, but in the lower atmosphere where ammonia is also required, this is insufficient to account for aerosol formation and additional trace vapours must be involved. The next step is to find more about these trace vapours, including whether they are of natural or human origin.

(iii) Volcanism

Volcanic eruptions release gases and particulates into the atmosphere. Eruptions large enough to affect climate occur on average several times per century, and cause cooling (by partially blocking the transmission of solar radiation to the Earth's surface) for a period of a few years. The eruption of Mount Pinatubo in 1991, the second largest terrestrial eruption of the 20th century (after the 1912 eruption of Novarupta affected the climate substantially. Global temperatures decreased by about 0.5 °C (0.9 °F). The eruption of Mount Tamborain 1815 caused the Year without a summer. Much larger eruptions, known as large igneous provinces, occur only a few times every hundred million years, but may cause global warming and mass extinctions.

Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the Earth's crust and mantle, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. Although volcanoes are technically part of the lithosphere, which itself is part of the climate system, the IPCC explicitly defines volcanism as an external forcing agent.

(iv) Plate tectonics

Over the course of millions of years, the motion of tectonic plates reconfigures global land and ocean areas and generates topography. This can affect both global and local patterns of climate and atmosphere-ocean circulation.

The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. A recent example of tectonic control on ocean circulation is the formation of the Isthmus of Panama about 5 million years ago, which shut off direct mixing between the Atlantic and Pacific Oceans. This strongly affected the ocean dynamics of what is now the Gulf Stream and may have led to Northern Hemisphere ice cover. During the Carboniferous period, about 300 to 360 million years ago, plate tectonics may have

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triggered large-scale storage of carbon and increased glaciations. Geologic evidence points to a "mega monsoonal" circulation pattern during the time of the supercontinent Pangaea, and climate modelling suggests that the existence of the supercontinent was conducive to the establishment of monsoons.

The size of continents is also important. Because of the stabilizing effect of the oceans on temperature, yearly temperature variations are generally lower in coastal areas than they are inland. A larger supercontinent will therefore have more area in which climate is strongly seasonal than will several smaller continents or islands.

(v) Human influences

In the context of climate variation, anthropogenic factors are human activities which affect the climate. The scientific consensus on climate change is "that climate is changing and that these changes are in large part caused by human activities," and it "is largely irreversible." Of most concern in these anthropogenic factors is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) and the CO_2 released by cement manufacture. Other factors, including land use, ozone depletion, animal agriculture and deforestation, are also of concern in the roles they play – both separately and in conjunction with other factors – in affecting climate, microclimate, and measures of climate variables.

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Science has made enormous inroads in understanding climate change and its causes, and is beginning to help develop a strong understanding of current and potential impacts that will affect people today and in coming decades. This understanding is crucial because it allows decision makers to place climate change in the context of other large challenges facing the nation and the world. There are still some uncertainties, and there always will be in understanding a complex system like Earth's climate. Nevertheless, there is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that these changes are in large part caused by human activities

— United States National Research Council, Advancing the Science of Climate Change

Physical evidence

Evidence for climatic change is taken from a variety of sources that can be used to reconstruct past climates. Reasonably complete global records of surface temperature are available beginning from the mid-late 19th century. For earlier periods, most of the evidence is indirect climatic changes are inferred from changes in proxies, indicators that reflect climate, such as vegetation, ice cores, dendrochronology, sea level change, and glacial geology.

ISBN: 978-93-85822-63-6

(i) Temperature measurements and proxies

The instrumental temperature record from surface stations was supplemented by radiosonde balloons, extensive atmospheric monitoring by the mid-20th century, and, from the 1970s on, with global satellite data as well. The $^{18}O/^{16}O$ ratio in calcite and ice core samples used to deduce ocean temperature in the distant past is an example of a temperature proxy method, as are other climate metrics noted in subsequent categories

(ii) Glaciers

Glaciers are considered among the most sensitive indicators of climate change. Their size is determined by a mass balance between snow inputs and melt output. As temperatures warm, glaciers retreat unless snow precipitation increases to make up for the additional melt; the converse is also true. Glaciers grow and shrink due both to natural variability and external forcing. Variability in temperature, precipitation, and englacial and sub glacial hydrology can strongly determine the evolution of a glacier in a particular season. Therefore, one must average over a decadal or longer time-scale and/or over a many individual glaciers to smooth out the local short-term variability and obtain a glacier history that is related to climate.

Glaciers leave behind moraines that contain a wealth of material—including organic matter, quartz, and potassium that may be dated—recording the periods in which a glacier advanced and retreated Similarly, by tephrochronological ,the lack of

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glacier cover can be identified by the presence of soil or volcanic tephra horizons whose date of deposit may also be ascertained.

(iii) Arctic sea ice loss

The decline in Arctic sea ice, both in extent and thickness, over the last several decades is further evidence for rapid climate change. Sea ice is frozen seawater that floats on the ocean surface. It covers millions of square miles in the Polar Regions, varying with the seasons. In the Arctic, some sea ice remains year after year, whereas almost all Southern Ocean or Antarctic sea ice melts away and reforms annually. Satellite observations show that Arctic sea ice is now declining at a rate of 11.5 percent per decade, relative to the 1979 to 2000 average.

(iv) Vegetation

A change in the type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO_2. A gradual increase in warmth in a region will lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant bio-cycles to lag. Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances. An example of this occurred during the Carboniferous Rainforest Collapse (CRC), an extinction event 300

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million years ago. At this time vast rainforests covered the equatorial region of Europe and America. Climate change devastated these tropical rainforests, abruptly fragmenting the habitat into isolated 'islands' and causing the extinction of many plant and animal species.

Satellite data available in recent decades indicates that global terrestrial net primary production increased by 6% from 1982 to 1999, with the largest portion of that increase in tropical ecosystems, then decreased by 1% from 2000 to 2009.

(v) Precipitation

Past precipitation can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse, but, reducing reliance on interpolation, satellite data has been available since the 1970s. Quantification of climatologically variation of precipitation in prior centuries and epochs is less complete but approximated using proxies such as marine sediments, ice cores, cave stalagmites, and tree rings.

Climatologically temperatures substantially affect precipitation. For instance, during the Last Glacial Maximum of 18,000 years ago, thermal-driven evaporation from the oceans onto continental landmasses was low, causing large areas of extreme desert, including polar deserts (cold but with low rates of precipitation). In contrast, the world's climate was wetter than today near the start of the warm Atlantic of 8000 years ago.

ISBN: 978-93-85822-63-6

Estimated global land precipitation increased by approximately 2% over the course of the 20th century, though the calculated trend varies if different time endpoints are chosen, complicated by ENSO and other oscillations, including greater global land precipitation in the 1950s and 1970s than the later 1980s and 1990s despite the positive trend over the century overall. Similar slight overall increase in global river runoff and in average soil moisture has been perceived.

(vi) Dendroclimatology

Dendroclimatology is the analysis of tree ring growth patterns to determine past climate variations. Wide and thick rings indicate a fertile, well-watered growing period, whilst thin, narrow rings indicate a time of lower rainfall and less-than-ideal growing conditions

(vii) Ice cores

Analysis of ice in a core drilled from an ice sheet such as the Antarctic ice sheet, can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO_2 variations of the atmosphere from the distant past, well before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO_2over many millennia, and continues to provide valuable information about the differences between ancient and modern atmospheric conditions.

ISBN: 978-93-85822-63-6

(viii) Animals

Remains of beetles are common in freshwater and land sediments. Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not altered significantly over the millennia, knowledge of the present climatic range of the different species, and the age of the sediments in which remains are found, past climatic conditions may be inferred.

Similarly, the historical abundance of various fish species has been found to have a substantial relationship with observed climatic conditions. Changes in the productivity of autotrophs in the oceans can affect marine food webs.

(ix) Sea level change

Global sea level change for much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long-term average. More recently, altimeter measurements in combination with accurately determined satellite orbit have provided an improved measurement of global sea level change. To measure sea levels prior to instrumental measurements, scientists have dated coral reefs that grow near the surface of the ocean, coastal sediments, marine terraces, , and near shore archaeological remains. The predominant dating methods used are uranium series and radiocarbon, with cosmogony being sometimes used to date terraces that have experienced relative sea level fall. In the early

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Pliocene, global temperatures were 1–2°C warmer than the present temperature, yet sea level was 15–25 meters higher than today.

Climate change-threats and vulnerabilities for India

Climate change has enormous implications for Indian agriculture, natural resources, livelihood and food security. Climate change will directly and indirectly affect the agricultural production, water resources, and natural ecosystem, and biodiversity, animal and human health. The Indian Network for climate change Assessment (INCCA) Report warns of impact such as sea level rise, increase in cyclonic intensity, reduce crop yield in rainfed crops, stress on livestock, reduction in milk productivity, increased flooding, and spread of malaria.

The food and nutrition security of India currently depends to a great extent on the production of wheat and rice which together constitute around 75 percent of total food grain production simulation models suggest that in absence of adaptation an fertilizer benefits, a 1 ^{0}C increase in temperature alone could lead to a 6 million tonnes drop in wheat production (Economic Survey 2011-12). Production of milk may also be adversely affected by the increased heat stress associated with global climate change to dairy animals. Heat stresses, vector borne diseases, water contamination are some of the projected health impacts of climate change.

Rice is the major crop as a source of livelihood of Bhandara district in Maharashtra. There is a tremendous impact of climate

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change directly on rice production and so the indirect effect on the sustainable livelihood of the farmers of Bhandara and Sakoli block of Bhandara district in Maharashtra. There is tremendous reduction in the annual rice production due to the pests and disease attack and the unfavourable climatic conditions. So hampered the Sustainable livelihoods of the selected Rice grower of Bhandara district.

Sustainability

Sustainability could be defined as an ability or capacity of something to be maintained or to sustain itself. It's about taking what we need to live now, without jeopardising the potential for people in the future to meet their needs.

If an activity is said to be sustainable, it should be able to continue forever. Some people say it is easy to recognise activities that are unsustainable because we know it when we see it. Think of extinction of some species of animals, often due to the activities of humans. Or salinity (salt) in our rivers due to changed land management practices. And at home, the amount of packaging you put in the bin that has to go into landfill.

Sustainable development

Sustainable development is an organizing principle for human life on a finite planet. It posits a desirable future state for human societies in which living conditions and resource-use meet human needs without undermining the sustainability of natural systems

ISBN: 978-93-85822-63-6

and the environment, so that future generations may also have their needs met.

The concept of sustainable development has in the past most often been broken out into three constituent domains: environmental sustainability, economic sustainability and social sustainability. However, many other possible ways to delineate the concept have been suggested. For example, the Circles of Sustainability approach distinguishes the four domains of economic, ecological, political and cultural sustainability. These accords with the United Cities and local governments specifying of culture as the fourth domain of sustainability. Other important sources refer to the fourth domain as 'institutional' or as 'good governance.'

Sustainable agriculture

Sustainable agriculture may be defined as consisting of environmentally friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems. More specifically, it might be said to include preventing adverse effects to soil, water, biodiversity, surrounding or downstream resources as well as to those working or living on the farm or in neighbouring areas. Furthermore, the concept of sustainable agriculture extends intergenerational, relating to passing on a conserved or improved natural resource, biotic, and economic base instead of one which has been depleted or polluted. Some important elements of sustainable agriculture

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are permaculture,agroforestry, mixed farming, multiple cropping, and crop rotation.

The sustainable livelihoods approach to poverty

Three factors shed light on why the SL approach has been applied to poverty reduction. The first is the realization that while economic growth may be essential for poverty reduction, there is no automatic relationship between the two since it all depends on the capabilities of the poor to take advantage of expanding economic opportunities. Thus, it is important to find out what precisely it is that prevents or constrains the poor from improving their lot in a given situation, so that support activities could be designed accordingly.

Secondly, there is the realization that poverty as conceived by the poor themselves is not just a question of low income, but also includes other dimensions such as bad health, illiteracy, lack of social services, etc., as well as a state of vulnerability and feelings of powerlessness in general. Moreover, it is now realized that there are important links between different dimensions of poverty such that improvements in one have positive effects on another. Raising people's educational level may have positive effects on their health standards, which in turn may improve their production capacity. Reducing poor people's vulnerability in terms of exposure to risk may increase their propensity to engage in previously untested but more productive economic activities, and so on.

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Finally, it is now recognized that the poor themselves often know their situation and needs best and must therefore be involved in the design of policies and projects intended to better their lot. Given a say in design, they are usually more committed to implementation. Thus, participation by the poor improves project performance

Sustainable livelihood approach (SLA) under climate change condition

Case study in Narail district of Bangladesh

A sustainable livelihood framework has been built for the study area following the sustainable livelihood approach (SLA) referred by DFID. While having this framework, the local people recommendations were taken into account as this will suit for them most and the ultimate goal of SLA can be achieved by offering a sustainable livelihood strategy from study area point of view.

Study showed that the framework in this study for farmer group. Similar framework has been developed for other livelihoods groups. Due to space limitations, we have only shown the SLA frameworks for farmers group.

The sustainable livelihood framework has been developed based on the assets which have been found vulnerable due to climate change as SLA has been formulated keeping the livelihood capitals in the centre. The affected assets were investigated to figure out the vulnerability extent and features and possible and effective direct measures have been set to

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reduce the vulnerability. Then, some suitable indirect measures for the study area have been proposed which will be undertaken by the local and government agencies. These two will protect the assets from the climate change threat and increase the local people's access to assets. At the same time, some sustainable livelihood strategies have been worked out so that the people can continue with their livelihood overcoming shocks and stresses to achieve livelihood outcomes such as food security, good health, etc (. Muhammad Anowar Saadat1* and A.K.M. Saiful Islam, 2011)

Detailed information about Rice, Rice production by Conventional method & SRI (System of rice intensification) method.

Rice:

General information

Rice is the staple food for more than 60 per cent of the world's population. It is the staple food of most of the people of south Eastern –Asia. About 90 percent of all rice grown in the worlds is produced and consumed in the Asian region. In India, rice is the most important and extensively grown food crop, occupying about 44.8 million hectors of land.

Rice cultivation is well-suited to countries and regions with low labour costs and high rainfall, as it is labour-intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide.

Rice occupies a pivotal place in Indian agriculture and is the staple food for more than 70 percent of population and a source of livelihoods for about 43 percent of total food grain production and 55 percent of cereals production in the country.

Rice is primarily a high energy or high calorie food. It contains less protein that wheat. The protein content of milled rice is usually 6 to 7 percent. Rice, however, compares favourably with other cereals in amino acids content. The biological value of its protein is high. The fat content of rice is low (2.0 to 2.5 percent) and much of the fat is lost during milling. Rice contains a low per centage of calcium. Rice grain contains as much B group vitamins as wheat. Milled rice losses valuable proteins, vitamins and minerals in the milling process during which the embryo and the aleuronic layer are removed. Much of the loss nutrients can be avoided through parboiling process.

The by-products of rice milling are use for a variety of purposes. Rice bran is used as cattle and poultry feed. Rice hulls can be used in manufacture of insulation materials, cement, and cardboard and as a litter in poultry keeping. Rice straw can be used as cattle feed as well as litter during winter.

In Vidarbha, total yield of rice cultivation during 2006-2007 was 10,571 metric tonne while total yield figures in Gadchiroli, Chandrapur, Bhandara and Gondia was 2306, 2287, 3026 and

ISBN: 978-93-85822-63-6

2008 metric tons respectively. Considering the large yield gap, there is wide scope for increasing the production of rice by adopt Rice is the most important source of food for farmers in Bhandara district, and non adoption of improvement package of practices is important constraint noticed.

In Bhandara district, total yield of rice cultivation during 2009-2010 was 1976.00 metric tonnes. Considering the large yield gap, there is wide scope for increasing the production of rice by adopting the improved cultivation practices by farmers.

Bhandara is one of the district of Maharashtra and is the district of lakes and also called as the “rice bowl of Maharashtra” which is situated under the Nagpur division. There are 7 talukas under this division namely as Bhandara, Mohadi, Tumsar, Sakoli, Lakhani, Lakhandur and Pavani. In the selected blocks of Bhandara district i.e. Bhandara and Sakoli, where the conventional and SRI method is followed predominantly.

Origin and history

Rice cultivation probably dates back to the antiquity and has probably been the staple food and the first cultivated crop in Asia. In India rice has been cultivated since ancient times. This is supported by archaeological evidences and by the numerous references made to rice in ancient Hindu scriptures and literature. Carbonised paddy grains were found in the excavations at Hasthinapur (Uttar Pradesh) at a side dated between 1000-750 B.C. (Choudhary and Ghose, 1953). This is the oldest rice

ISBN: 978-93-85822-63-6

specimen yet known in the world. From the study of Sanskrit and of other different languages in south-eastern Asia, many investigators have come to the conclusion that rice was known in India before the present era.

De Candolle (1886) and Watt (1892) through that south India was the place where cultivated rice originated. Vavilov (1926) suggested that India and Burma should be regarded as the centre of origin of cultivated rice.

Area and distribution

Rice is the world's leading food crop, cultivated over an area of about 155 million hectares with a production of about 596 million tonnes (paddy). In terms of area and production it is second to wheat. It provides about 22 percent of the world's supply of calories and 17 percent of the proteins. Maximum area under rice is in Asia. Among the rice growing countries, India has the largest area (44.8 million hectares) followed by China and Indonesia. In respect of production, India ranks second with 131 million tonnes of paddy next to china (200 million tonnes of paddy). In regard to average yield per hectare, Egypt ranks first followed by USA. Average rice yield of India is only 2929 kg per hectare.

In India rice is grown in almost all the states. Andhra Pradesh, Bihar, Uttar Pradesh, Madhya Pradesh and West Bengal lead in the area. West Bengal and U.P. have the highest rice production. The average yield per hectare is highest in Punjab (3346kg/ha).

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In the east vidarbha region of Maharashtra state,7 Lac hectare area was under the paddy with total yield 10 lac tonne and productivity was 14.0q/h.(2010-2011)

Classification

Rice belongs to genus Oryza of Gramineae family. The genus Oryza includes 24 species, of which 22 are wild and two namely Oryza sativa and Oryza glaberrima are cultivated. All the varieties found in Asia, America and Europe belong to O. sativa and varieties found in West Africa belong to species O. glaberrima.

Oryza sativa is a diploid species having 24 chromosomes. The sativa ice varieties of the world are commonly grouped into three subspecies namely indica, japonica and javanica.

1) **Indica**: Rice grown in India belongs to the indica subspecies. They are characterised by having leaves slightly pubescent and pale green in colour. Indica are awn less or possess short and smooth awns. The fruit is caryopsis, elongated, thin, narrow and slightly flattened

2) **Japonica**: The varieties developed in Japan belong to this subspecies. These varieties are adapted for cultivation in the sub tropical and warm temperate regions. Japonica varieties mostly have oval and round grains. They may be awned or awn less. Leaves are narrow and dark green in colour.

3) **Javanica**: They are characterised by a stiff straw, long panicle with awned grains, spares tillering habit, long duration and low sensitivity to difference in day length. These are found mostly in Indonesia.

ISBN: 978-93-85822-63-6

Botanical description:

The rice plant (Oryza Sativa L.) is a member of Gramineae family. The common cultivated rice plant is an annual which usually grows to a height of half a metre to two metres but there are certain verities that grow much taller (6-9 metres). Some deep water rice varieties grow with the gradual rise of the flood water level. Rice plant can be divided into two main parts namely root system and shoot system.

Root system

The root system is fibrous. Soon after sowing; rice seed gives out seminal roots out of the radical. These are temporary in nature. The real functional roots are secondary adventitious roots that are produced from the lower nodes of the Culm.

When a rice grain germinates in a well drained, upland soil the sheath (coleorhizae) emerges. If it germinates in submerged low lands, the coleoptiles emerge ahead of the coleorhizae. The primary, embryonic root (radical) comes out through the coleorhizae shortly after it appears. This is followed by two or more secondary roots, all of which develop lateral roots. The embryonic roots later die and are replaced by secondary adventitious roots produced from the underground nodes of the Culm.

Shoot system

The rice stem known as Culm is hollow and is made up of nodes and internodes. Each node bears a leaf and bud, which may grow

ISBN: 978-93-85822-63-6

into a shoot or tiller. Primary tillers grow out of the main Culm. Tillering continues in rice up to vegetative phase. Some tillers die during the reproductive phase due to competition for water and nutrients. Panicles bearing tillers are known as fertile or productive tillers.

Collectively applies to all plants visible above the ground level. It is mainly composed of culms, leaves and inflorescence (panicle).

Culm: the Culm or stem is made up of a series of nodes and internodes. The rice culms are usually hollow except at the nodes.

Leaf: Each node of the Culm bears a leaf. Each leaf consists of the following parts:

Leaf sheath: It originates from the node of Culm and many a times encloses it and sometimes even the next upper node and a part of the leaf sheath of the upper leaf.

Leaf blade: It is the upper expanded part of leaf and begins at node, where it is joined with leaf sheath. At the joint there is a thick collar.

Auricles: These are hairy appendages at the base of the leaf blade.

Ligules: It is a thin papery structure just above the auricles. Different parts of leaf are of importance in identifying the varieties.

Flag leaf: It is the uppermost leaf just below the panicle. It is generally shorter in length and remains erect at an angle

ISBN: 978-93-85822-63-6

Panicle: The inflorescence of rice plant is born on terminal shoot and is known as panicle. It is determinate type and at maturity it is droopy in nature. Panicle bears the spikelets.

Spikelet: A spikelet is the floral unit and consists of two sterile lemmas, a lemma, a palea and the flower.

Lemma: It is a 5 nerved hardened bract with a filiform extension known as awn. Rice varieties may or may not have an awn.

Palea: It is a three nerved bract slightly narrower than lemma.

Flower: It consists of 6 stamens with two -celled anthers and a pistle with one ovary and two stigmas. The pistil consists of one ovule

Grain:

- Rice grain is the ripened ovary with lemma and palea firmly adhered to it.
- The lemma and palea with other smaller components from the hull are removed in shelling rice for consumption.
- The rice fruit is a caryopsis in which single seed is fused with the wall of the ovary (paricarp).
- The seed consists of endosperm and an embryo. The embryo is very small and is found on the ventral side of the caryopsis. It contains plumule (embryonic leaves) and radicle (root).
- On submergence in water or on sowing the radicle grows as root and plumule grows as shoot.

Climatic requirements

In India rice is grown under widely varying condition of altitude and climate. Rice cultivation in India extends from 8 to 35^{o} N latitude and from sea level to as high as 3000 metres. Rice crop

ISBN: 978-93-85822-63-6

needs a hot and humid climate. It is best suited to regions which have high humidity, prolonged sunshine and an assured supply of water. The average temperature required throughout the life period of the crop ranges from 21 to 37^{o}C. At the time of tillering the crop requires a higher temperature than growth. Temperature requirement for blooming is in the range of 26.5 to 29.5^{o}C. At the time of ripening the temperature should be between 20-25^{O}C. Photo periodically, rice is a short day plants. However, there are varieties which are non-sensitive to photoperiodic conditions.

Rice growing season

Rice-growing seasons vary in different parts of India, depending upon temperature, rainfall and other climatic conditions. In parts of eastern region and Peninsular India, the mean temperatures throughout the year are favourable for rice cultivation and hence two or three crops of rice are taken in a year. In northern and western parts of the country where winter temperatures are fairly low only one crop of rice is taken during Kharip season. There are three seasons for growing rice in India as given below:

Table 2.1: Seasons for growing rice in India

Crop season	Local name	Sowing time	Harvesting time
Kharip	Aus (W.B.,Bihar)	May-June	Sep-Oct
Rabi	Aman or Aghani	June-July	Nov-Dec
Summer	Boro (W.B)	Nov-Dec	March-April

Table 2.1, showed that, rice-growing seasons in Maharashtra are mainly Kharip and summer. Kharip season sowing time is

ISBN: 978-93-85822-63-6

May-June and summer season sowing time is Nov-Dec. Harvesting time of Kharip season is September-October and summer season harvesting time is March-April.

Soil

In India rice is grown under so diverse soil conditions that it can be said that there is hardly any type of soil in which it cannot be grown, including alkaline and acidic soils. Soil having good water retention capacity with good amount of clay and organic matter are ideal for rice cultivation. Clay or clay loams are most suited for rice cultivation. Such soils are capable of holding water for long and sustain crop. Rice being a semi-aquatic crop grows best under submerged conditions. A major part of Rice crop in India is grown under 'Low land' conditions. Rice plant is able to tolerate a wide range of soil reaction, but it does have a preference for acidic Soils. It grows well in soils having a Ph range between 5.5. & 6.5.

Varieties

The dwarf high yielding varieties, no doubt, have higher yield potential than the traditional or so called tall varieties under low fertility too; the high yielding dwarf varieties yield comparatively more than the traditional tall varieties. Today in our country there are quite a good number of varieties suitable for different agro-climatic regions. Selection of verities depends to a great extent on the agro- climatic conditions, the cropping system followed,

ISBN: 978-93-85822-63-6

grain quality and several other factors. While selecting a suitable variety the following factors should be taken into consideration.

Table 2.2: Released varieties of rice suitable for cultivation in different ecosystem of Maharashtra.

State	Ecosystem	Name of the varieties
Maharashtra	Rainfed upland	Tulijapur-1,Imp,Ambemohar,
	Irrigated early	Prabhavati, Ambika, Karjt 1,Ratnagiri 1, Pawana, Sakoli 6, Terna, SYE-ER 1, Sugandha,Karjat 4.. Karjat 184, Palghar 60, Ratnagiri 24, Suhasini, Surya, Radhangiri 185, Jalgaon 5,Ratnagiri 71-1-41,
	Irrigated medium	Satya, ACK 5, Panvel 2, Indrayni, Palghar 1, Kundalika, Karjat 2, Ratnagiri 3, Sahyadri,Pondaghat 1, Phule Mawal, HMT Sona.
	Rainfed shallow lowland	SYE 75, Darana, Ratnagiri 2
	Saline alkaline	Panvel 1, Sindewahi 1, Panvel 3, CSR 10, CSR 13,CSR 27
	Scented	SKL 47-8, Karjat 3

Source: High yielding rice varieties of india-2000, Directorate of Rice Research, Indian Council of Agricultural Research, Rajendra Nagar, Hyderabad, A.P.

Table 2.2, showed that, varieties of rice suitable for cultivation under Rainfed upland ecosystem are Tulijapur-1, Imp, and Ambemohar. Varieties of rice suitable for cultivation under Irrigated Early ecosystem are Prabhavati, Ambika, Karjt 1,Ratnagiri 1, Pawana, Sakoli 6, Terna, SYE-ER 1, Sugandha,Karjat 4.. Karjat 184, Palghar 60, Ratnagiri 24,

ISBN: 978-93-85822-63-6

Suhasini, Surya, Radhangiri 185, Jalgaon 5, Ratnagiri 71-1-41. Varieties of rice suitable for cultivation under Irrigated Medium ecosystem are Satya, ACK 5, Panvel 2, Indrayni, Palghar 1, Kundalika, Karjat 2, Ratnagiri 3, Sahyadri,Pondaghat 1, Phule Mawal, HMT Sona. Varieties of rice suitable for cultivation under Rainfed shallow lowland ecosystem are SYE 75, Darana, Ratnagiri 2. Varieties of rice suitable for cultivation under Saline alkaline ecosystem are Panvel 1, Sindewahi 1, Panvel 3, CSR 10, CSR 13, CSR 27 and Varieties of rice suitable for cultivation under Scented ecosystem are SKL 47-8, Karjat 3.

Table 2.3: List of varieties resistance to pests and diseases suitable for cultivation in Maharashtra.

State	Ecosystem	Name of the varieties
Maharashtra	Blast	ACK 5,Ambika, HMT Sona, Indrayani,Karjat 1, Panvel 1, Palghar 1, Palghar 60, Phule Mawal, Radhanagiri 185-2, Ratnagiri 73-1, Ratnagiri 1, Ratnagiri 3, Sakoli-6, SYE 75, Terna.
	BLB (Bacterial Leaf Blight)	ACK 5, HMT Sona, Karjat 1, Radhanagiri 185-2, Ratnagiri 73-1, Ratnagiri 1, Ratnagiri 3, Sakoli-6,
	GM (Gall Midge)	Ratnagiri 1, Ratnagiri 3,

Source: High yielding rice varieties of india-2000, Directorate of Rice Research, Indian Council of Agricultural Research, Rajendra Nagar, Hyderabad, A.P.

Table 2.3, showed that, varieties of rice resistance to Blast are ACK 5,Ambika, HMT Sona, Indrayani,Karjat 1, Panvel 1, Palghar 1, Palghar 60, Phule Mawal, Radhanagiri 185-2, Ratnagiri

ISBN: 978-93-85822-63-6

73-1, Ratnagiri 1, Ratnagiri 3, Sakoli-6, SYE 75, Terna. varieties of rice resistance to BLB(Bacterial Leaf Blight) are ACK 5, HMT Sona, Karjat 1, Radhanagiri 185-2, Ratnagiri 73-1, Ratnagiri 1, Ratnagiri 3, Sakoli-6 and varieties of rice resistance to GM(Gall Midge) are Ratnagiri 1, Ratnagiri 3.

Hybrid rice

At the current rate of population growth, which is accelerating at 1.8 per cent, rice requirement but 2020 would be around 140 million tonnes, which is about 89.5 million tonnes during 1999-2000. Achieving the targeted production would be a challenging task as the productivity increases has to come from the declining and degrading resource base in terms of land, water, labour, and other inputs. Among the available genetic options to raise the yield ceiling further, hybrid rice appears to the most feasible and readily adaptable technology to our conditions as has been successfully demonstrated in China

Cropping system

In North India where irrigation facilities exist, a number of cropping system of crops involving rice are feasible. After harvest of rice, rice, crops like potato, berseem toria, etc, can be sown and will fit very well in intensive crop rotations. In rainfed areas too, where the soils are well drained and have good moisture retention capacity, legume crop like chick pea, lentil could be grown successfully after the harvest of rice, which mature on the

ISBN: 978-93-85822-63-6

residual moisture in the soil. Some of the cropping systems are given below:

(A) Irrigated area

1. Rice – Wheat
2. Rice – Potato – Black Gram
3. Rice – Toria – Wheat
4. Rice – Wheat – Green Gram
5. Rice – Potato – Green Gram
6. Rice – Pea – Green Gram
7. Rice – Wheat – Jute
8. Rice – Field Peas – Sugarcane.

(B) Un -irrigated area

1. Rice – Chickpea
2. Rice – Lentil
3. Rice – Field Pea

In case of intensive crop rotations where there are more than two crops in a year, a paddy variety of early duration should be selected

In south India, where the winter temperature is not so low, double cropping of rice is practiced. In eastern India, in low lying areas a crop of jute is grown followed by rice. Some of the cropping systems are as below:

1. Rice – Rice –Wheat
2. Jute- Rice-Wheat
3. Rice – maize – Jute
4. Rice – Potato – Jute

ISBN: 978-93-85822-63-6

Method of cultivation of rice

In India rice is grown mainly on two types of soils i.e., upland and low lands. The system of rice cultivation in a region depends largely on factors such as situation of the land, type of land, type of soil, irrigation resources, and availability of labourers, intensity and distribution of rainfall etc. The following are the principal system of rice cultivation.

1. Dry or semi-dry upland condition

a) Broadcasting the seed

b) Sowing the seed behind the plough or drilling

c) Dry or semi-dry upland condition

2. Wet or lowland cultivation

a) Transplanting in puddle soil.

b) Broadcasting sprouted seeds in puddle soil.

In the present study rice is cultivated by two method- 1) Conventional method/traditional method (2) SRI (System of rice intensification) Method.

ISBN: 978-93-85822-63-6

Detail information about rice production through Conventional method and SRI method.

Field preparation / Preparatory tillage

Conventional method

After harvesting the Rabi crops in April-May, the field should be ploughed with soil turning plough. This is helpful in weed eradication as well as improvement in the water holding capacity of the soil. The field should be prepared and bunds should be made around the field just after the first shower of monsoon. This will check loss of rain water by runoff. After the field preparation use 25 to 30 bullock cards (10 tonnes) of farm yard manure or compost manure per hectare on the prepared field.

SRI method

Pre-soak the rice field for 4-5 days followed by one deep ploughing and 2-3 harrowing with 2-3 days interval to ensure proper soil-water mixture. Apply basal dose of fertilizer, preferably organic, before the last harrowing followed by levelling the field for maintaining uniform water level throughout the field. Prepare grids in the muddy field with the help of rake made up of wood, bamboo or iron in such a way that too much standing water is not left in the field. Spacing of the square grid should be of 25 cm x 25 cm in case of moderately fertile land and up to 40 cm x 40cm in case of well fertile land.

ISBN: 978-93-85822-63-6

Selection of varieties

Conventional method

Short duration varieties of 100-105 days duration should be selected

SRI method

Any improved or Hybrid and varieties with heavy tillering should selected

Seed rate/hectare

Conventional method

Use 35 kg/ha. Seed for fine grain variety.

Use 50 kg/ha. Seed for bold grain variety.

In SRI method- Use only 5 kg seed/ha.

Seed treatment for both methods

a) Make a solution of 300 gm salt in 10 litre of water and then add the paddy seed in it before sowing. When the solution is constant remove the light weighted seed and then burn it. (b) Wash the heavy seed 3 times with clean water which are placed at the bottom side and then dry in the shed before sowing.(c) seed should be treated with 3 gm thirum/1kg seed before sowing. These techniques are applicable in both method of cultivation.

Seedling preparation

Conventional method

Prepare the land by ploughing and harrowing. Prepare the seed bed with proper length, 100cm width, and 10 to 15 cm height. In

ISBN: 978-93-85822-63-6

every square metre add 3 kg decomposed organic manure and 10 gm urea or 20 gm ammonium sulphate with proper mixing. If there is any problem regarding seed sowing in the raised seed bed then prepare the plane seed bed for seedling preparation. If there is irregular rainfall situation then watering should be done to the seed bed. Seed should be sown just after the start of rainy season with 7-8 cm distance in a line and 2 cm deep then cover it. Give the 10 gm of urea per square metre for seed bed after 15 days. In 20to 30 days seedlings will be ready for transplanting.

SRI method

Use 5 kg seed per ha. Select only good quality seed for sowing. This can be done by soaking the seed 24 hr in salt water then keep it for 36 hr in wet gunny bag for sprouting. Then seed must be treated with 2 – 3 kg thirum (fungicide) per kg of seeds. For the proper growth of sprouted seed prepare 5 cm level of decompose organic manure/ vermicompost over the seed bed and spread in level. In this way using only sinking seed for sowing. Transplanting should not be done in very close distance. Proper distance should be maintained. Spray organic fertilizer two days after sowing and spray organic pesticides if needed. Water the nursery daily to moist but not saturated. In 8 to 10 days that sprouted seeds become in two leaves then it will be ready for transplanting.

ISBN: 978-93-85822-63-6

Puddling

Conventional method

Puddling should be done with the help of wooden plough or power tiller or by tractor before cultivation. After the horizontal and vertical puddling levelling should be done. During puddling 50 % N and full dose of P and K should be given. During fertilizer application water should be harvested in the paddy field.

SRI method

In case of SRI use maximum amount of organic fertilizer, green manuring like *Subabul, Glyricidia Boru, Dhaincha*, etc at the time of puddling.

Transplanting

Conventional method

Transplanting shall be done when seedling are ready for transplanting. The seedlings are uprooted from the nursery at the optimum age (three to four weeks for short duration varieties and four to five weeks for medium and long duration varieties). Transplanting of the healthy seedlings may be done at the four to five leaf stages or when they are about 15-20 centimetres high. Delayed transplanting leads to poor tillering, early flowering of the main tillers and reduction in yield. Transplant two to three seedlings per hill at 20 x 10 centimetre distance under normal conditions. Increase the number of seedling per hill if old seedlings are used. For 45 days old seedlings the number of seedlings per hill should be five or six. In alkaline soils old

ISBN: 978-93-85822-63-6

seedlings (45 days old) establish better than young seedlings of 25 days ages or so. In each case seedlings should be transplanted at 2-3 centimetre depth. Seedlings should not be planted deeper than 2-3 centimetre as deeper planting delays and inhibits tillering. Planting in lines may not be necessary if adequate population is assured. There should be on an average, 50 hills per square metre to assure adequate population in rice field.

In wet or lowland cultivation of rice, transplanting is advantageous for the following reasons:

(1) It enables the cultivator to have optimum plant population at desired spacing in the field.

(2) It enables the cultivator to have an opportunity to give a through cultivation and puddling operation to the field which keeps down the weeds.

(3) Since the nurseries occupy only a small area of the field, the control of diseases and insect pests and irrigation and manuring of young crop is easier and cheaper than a broadcast or direct sown crop.

But now a day's transplanting has become very expensive due to high labour cost. A number of field experiments have shown that the productivity of direct seeded rice could be as high as from transplanted rice provided the weeds could be controlled effectively and the management level are high.

ISBN: 978-93-85822-63-6

SRI method

Wait for the puddle get constant (12 hours) in the field then remove all the water from the field first. Use only 8 to 10 days old seedling for transplanting. Make the square of 25 x 25 cm for late variety and 20 x 20 cm for early type of variety with the help of marker or by nylon rope. Precaution should be taken during uprooting the seedlings, so avoid the damaging of roots of the seedlings. So in this way only 1 seedling transplanted with soil not so deeper in a straight way in every corner of the squares. Transplanted seedling will be constant in 24 hour.

Nutrient management

Conventional method

Use the 25-30 cart load of decomposed organic manure or compost fertilizer in the paddy field. Insert the green manuring crops like dhaincha, Boru at the time of puddling inside the field. Save 30-40 kg or 10-20 Kg nitrogen by adding glyricidia leaves 5tonne/ha. Nutritional management must be done after the soil testing. The chemical fertilizer dose for paddy 100:50:50 kg nitrogen, phosphorous, and potash per ha. Give half dose of nitrogen and full dose of P and K at puddling stage and remaining 25 kg N during tillering stage and 25 kg N in booting stage.

SRI method

SRI Method is famous for those farmers who are doing organic farming. For doing fully Organic farming, it requires compost fertilizer and blue green algae in much amount. Use 8 to 10

ISBN: 978-93-85822-63-6

metric tonne organic manure/hectare before puddling in the field. Use 3kg azospyrilym/hectare for constant percentage of Nitrogen in air. Use 5 tonnes of compost or vermicompost/bio fertilizer and another use of green manuring like *subabul, dhencha, boru* etc. If it is not possible then use 50 % green manuring and 50 % of recommended dose of N, P and K.

Plant protection measure

Conventional method

Use the gall fly resistance variety of paddy like-sindewahi-2001, PKV Makarand, PKV Ganesh etc. Seedling must be free from gall fly before transplanting. Deeping of seedling in Chloropyriphos @ 10 ml/10 litre of water for stem borer control. For control of Gall Fly use 10 kg Phorate/ ha. For the control of Jassid, Army warm and leaf roler use of monocrotophos 14 ml/10 litre of water/ha or use of recommended insecticides. Spraying of streptocycline 0.5 and copper oxychloride in 10 litre of water properly mixed for control of blight.

SRI method

Give the leaves of *Cleistanthus collinus* 1.5 tonne/ha during puddling for the proper management of on gallfly attack. Use the gall fly resistance variety of paddy like-sindewahi-2001, PKV Makarand, PKV Ganesh etc. Seedling must be free from gall fly before transplanting. Use maximum amount of green manuring like- *Subabul, Glyricidia Boru, Dhaincha*, at the time of puddling

ISBN: 978-93-85822-63-6

and us of bio-fertilizer, organic manure for proper growth and development of the plant.

Water management

Conventional method

Maintain 2.5 cm water level in initial seedling period (in between 10 days). Increase the water level in the field up to 5cm till dough stage (grain filling). Removal of extra water time to time. Maintain the 10 cm water level in 10 days before grain filling and 10 days after grain filling. Then minimize the water level slowly-slowly and removal whole water in 10 days before harvesting.

SRI method

Water should not be stagnant during the growth stage. This period is up to 55 days from the time of transplanting. Irrigation should be provided only to moist the soil in the early period of 10 days. So precaution should be taken that there will be no any hairline cracks to the puddle. Restoring irrigation to a maximum depth of 2.5cm after development of hairline cracks in the soil until panicle initiation. This period is from 55 days after transplanting. Water given in this way that the Land must be continuously in intermittent situation. Restoring irrigation level up to 3-5cm from booting stage up to three weeks.

Weed management

Conventional method

Mulching and weeding is necessary in 15 days after sowing. Then again weeding and mulching is necessary in after 2 to 3 weeks.

ISBN: 978-93-85822-63-6

In this way remove all the weeds from the field. All the intercultural operation should be complete in one month before the grain feeling. Use of herbicides like butaclore(for control of grassy and broad-leaved weeds) 3.75 litre/ ha. or benthiocarb 3.75 litre/ha. or pendimethalin 2.75 litre/ha mixed in 700 litre of water and spraying 3-4 days after transplanting.

SRI method

Weeding is a biggest problem in SRI method because the water is not stored in the paddy field. At least 3 time weeding is necessary. In case of hand weeding, do not throw that weed outside the field and insert that uprooted weeds with the help of foots in the field. Using the implement 'cono weeder' for weed control which helps in less expenditure. Moving the weeder with forward and backward motion to bury the weeds and as well to aerate the soil at 7-10 days interval from 10-15 days after planting on either direction of the rows and column. Manual weeding is also essential to remove the weeds closer to rice root zone. Spraying the herbicide- (butaclore 3.75 litre +500 litre water)/ha. After transplanting up to 3-5 days for weed control.

Major weeds founds in east Vidarbha region on paddy field.

Due to the growth of weeds inside the paddy field, there is a 40 % reduction in the yield. So the weed control at proper time can help in increase the productivity. Some of the major weeds found in east vidarbha region are as follows:

ISBN: 978-93-85822-63-6

1) *Cyperus iria*
2) *Leptochloa chinensis*
3) *Sphenoclea zeylanica*
4) *Echinochloa glabrescens*
5) *Digitaria sanguinalis*
6) *Eleusine indica*
7) *Cyperus difformis*
8) *Monochoria vaginalis*
9) *Ipomoea aquatic*
10) *Oryza sativa*
11) *Echinochloa glabrescens*
12) *Echinochloa colona*
13) *Ischaemum rugosum*

Major insect pests and diseases with their control measure:

(A) Major insect pests of rice with their control measure

1) Stem borer:

Control measure-1) Stem borer resistant paddy varieties-Sakoli 8, sindewahi-5. (2) Before transplanting soak the plant roots in the mixture of Chloropyriphos 20 % EC 10 ml per 10 litre of water for 12 hour. (3) Paddy should be harvested at ground level. (4) First ploughing after harvest with stubble collection and burn

ISBN: 978-93-85822-63-6

it.(5) When there is a 5 % pests attack on tillers use immediately insecticides like fenitrothion 16 m.l., or quinalphos 32 m.l. mixing per 10 litre of water and spraying. Or spread at least 3 to 4 times Trichograma Japonicum @ 50000 /ha with the interval of seven days.

2) Gallfly:

Control measure-(1) Use resistant varieties like sindewahi-2001, Sakoli-8, P.K.V.Ganesh. (2) Eradication of competitive plants and stubbles. (3) Removing of infected plants. (4) Use 10 kg Phorate/ha.

3) Jassid:

Control measure-(1) Use resistant varieties like-sindewahi -1, sindewahi-5. (2) Planting should not be overcrowded. (3) Don't excess use of nitrogen. (3) Use of monocrotophos 14 ml/10 litre of water/ha.

4) Army worm:

Control measure- (1) Use of monocrotophos 36 % EC 14 ml or carboryl 50% 20 gm or cypermethrin 10 % EC 6 ml /10 litre of water and spraying /ha.

(B) Major diseases of rice with their control measure

1) Blast:(*Pyricularia grisea***)**

Control measure- (1) Use of resistant varieties like-RP-4-14, Ratna, Sakoli-6, IR-64. (2) Use the fungicides like Carbendazim

ISBN: 978-93-85822-63-6

10 gm or Hinosan 6m.l. or copper oxychloride 25 gm per 10 litres of water and spraying.

2) Bacterial leaf blight (*Xanthomonas compestris pv oryzae***)**

Control measure- (1) Adds Copper oxychloride 25 gm + streptocycline 0.5 gm in 10 litres of water and spaying.

3) Rice bunt (*Tilletia barclayana***)**

Control measure- Fungicides propiconazole (Tilt) 25 % 10 m.l. mixed in 10 litre of water and spraying at tillering and flowering stage.

4) False smut (*Ustilaginoidea virens***)**

Control measure-For the control of this disease soak the seed in 3 % salt water. Remove and burn the light seed and use the healthy seed for seed treatment before sowing of seed with thirum 3gm/kg

5) Tungro disease of rice

Control measure- (1) Use of systemic granular insecticides such as Carbofuran is considered to be most effective against tungro disease. Insecticide applied to the roots of plants provides the most efficient uptake and also much slower degradation rate [36]. (2) Uprooting the infected plants in the initial stage and burn it.

ISBN: 978-93-85822-63-6

Harvesting and threshing

Harvesting should be done in 25 to 30 days after fully grain filling stage when 90% grains are fully mature. Threshing should be done after fully drying of crop with the help of thresher or with the help of foots of bullocks.

Yield

Conventional method

Table 2.3.1: Early varieties of rice

Varieties	Days	Average yield q/h.
i) Sakoli-6	115-120	40 -50 q/h.
ii) Sindewahi-1	115-120	40-45 q/h.

Table 2.3.1, showed that the early varieties of rice are Sakoli-6 (115-120 days) with average yield 40 -50 q/h. and Sindewahi-1 (115-120 days) with 40-45 q/h. average yield.

Table 2.3.2: Medium varieties of rice

Varieties	Duration/days	Average yield q/h.
i) Sindewahi-75	135-140	50 -55 q/h.
ii) P.K.V.Ganesh	126-128	40-45 q/h.
iii) Sindewahi-4	135-140	40-45 q/h
iv) P.K.V. HMT	135-140	40-45 q/h
v) Sindewahi-2001	130-135	45-50 q/h
vi) Suraksha	135-140	40-45 /h

Table 2.3.2, showed that the Medium varieties of rice are Sindewahi-75 (135-140 days) with average yield 50 -55 q/h. P.K.V.Ganesh (126-128 days) with average yield 40-45 q/h.

ISBN: 978-93-85822-63-6

Sindewahi-4 (135-140 days) with average yield 40-45 q/h. P.K.V. HMT (135-140) with average yield 40-45 q/h. Sindeweahi-2001 (130-135 days) with average yield 45-50 q/h. Suraksha (135-140 days) with average yield 40-45 q/h.

Table 2.3.3: Late varieties of rice

Varieties	Days	Average yield q/h.
i) Sindewahi-5	145-150	50-55 q/h.
ii) Sakoli-8	140-145	40-45 q/h.

Table 2.3.3, showed that the late varieties of rice are Sindewahi-5 (145-150 days) with average yield 50-55 q/h and Sakoli-8 (140-145 days) with average yield 40-45 q/h.

Table 2.3.4: Scented varieties of rice

Varieties	Days	Average yield q/h.
i) Sakoli-7	130-135	40-45 q/h.
ii) P.K.V. Makarand	121-125	35-40 q/h.
iii) P.K.V. Khamang	130-135	35-40 q/h.

Table 2.3.4, showed that the Scented varieties of rice are Sakoli-7 (130-135 days) with average yield 40-45 q/h. P.K.V. Makarand (121-125 days) with average yield 35-40 q/h. and P.K.V. Khamang (130-135 days) with average yield 35-40 q/h.

ISBN: 978-93-85822-63-6

Table 2.3.5: Hybrid varieties of rice

Varieties	Days	Average Yield q/h.
i) Sahyadri	125-130	65-70 q/h.
ii) Sahyadri 2	115-120	60-65 q/h.
iii) Sahyadri 3	125-130	65-70 q/h.
iv) Sahyadri 4	115-120	60-65 q/h.

Table 2.3.5, showed that the hybrid varieties of rice are Sahyadri (125-130) with average yield 65-70 q/h. Sahyadri-2 (115-120 days) with average yield 60-65 q/h.

Sahyadri-3 (125-130 days) with average yield 65-70 q/h. and Sahyadri-4 (115-120 days) with average production 60-65 q/h.

SRI method

20-40% more yield than conventional method of rice cultivation due to much tillering (30-40 tillers/seedling).

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