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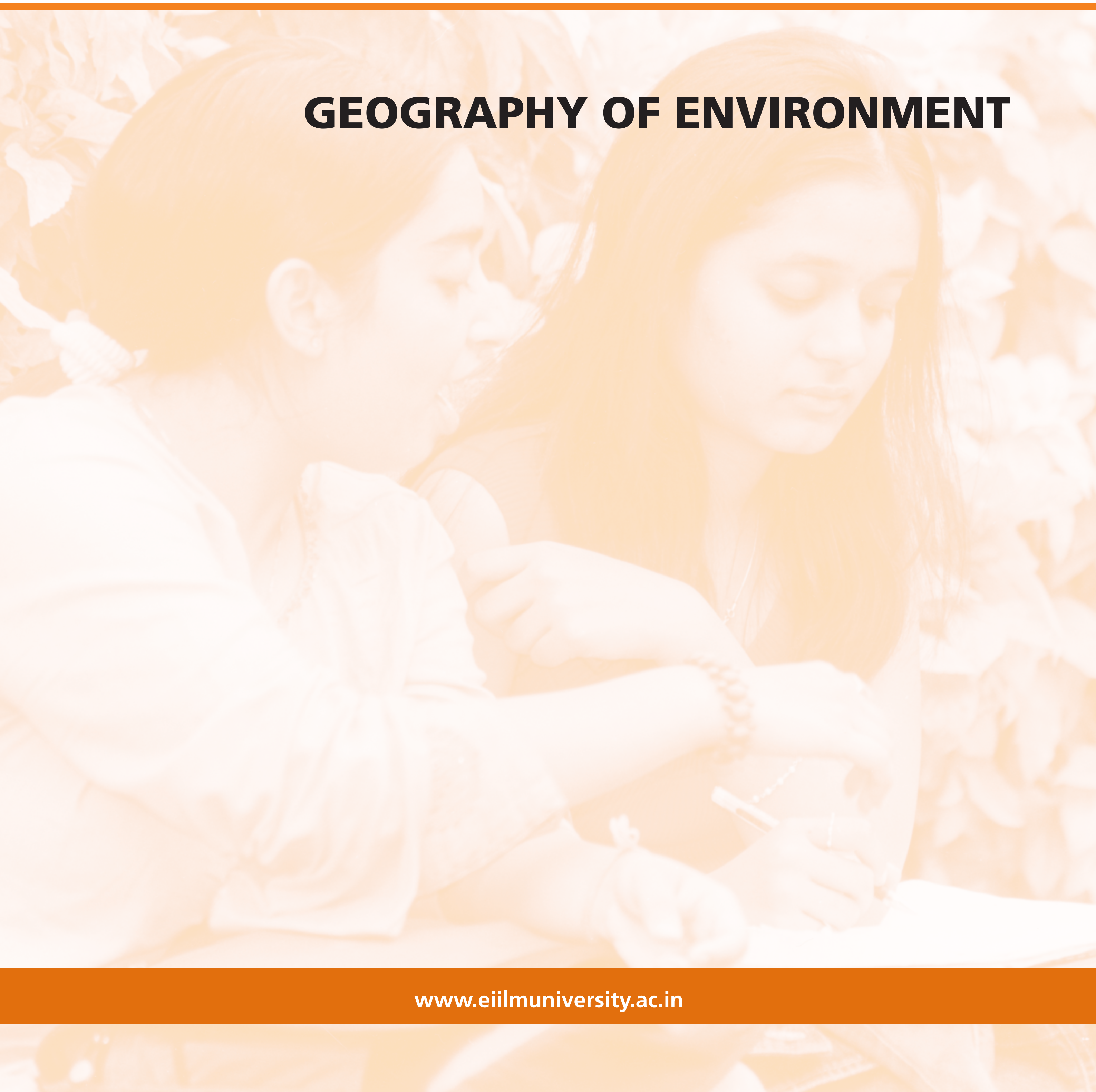
GEOGRAPHY OF ENVIRONMENT



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Subject: GEOGRAPHY OF ENVIRONMENT **Credits: 4**

SYLLABUS

Environmental Geography

Introduction to Environmental Geography: Meaning Definition, Nature & Scope, Ecology & Ecosystem; Environmental Hazards, Environmental Disaster & Stress, Classification of Environmental Hazards Environmental Movement: Chipko, Silent Valley & Narmada Bachao Andolan.

Environmental Hazards

Concept of Management of Environmental Hazards: Identification & Distribution of Hazards, Hazards Zonation and Risk Analysis, Hazard Awareness, Pre- Hazard Conditions: Warning & Precautions, Post Hazard Condition: Rescue, Assessment & Rehabilitation

Hazards & Disaster

Atmospheric Hazards & Disaster: Causes, Effects & Management, Cumulative Atmospheric Hazards Cyclone, Drought, Floods Green House effect & Global Warming Concept of Sustainable Development

Terrestrial Hazards

Terrestrial Hazards: Causes, Effects & Management, Earthquake, Landslide, Tsunami, Man- Induced Hazards: Causes, Effects & Management, Desertification, Forest Fire, Soil degradation & Population Explosion

Suggested Readings:

1. Arthur Strahler, Arthur Newell Strahler, Physical Geography: Science and Systems of the Human Environment, John Wiley & Sons

2. Colin Michael Hall, Stephen J. Page, The Geography of Tourism and Recreation: Environment, Place and Space, Routledge

3. Mohammad Shafi, Mehdi Raza, Geography of Environment, South Asia Books

4. Ashok K. Dutt, Facets of Social Geography: International and Indian Perspectives, Cambridge University Press

Chapter 1 - Environmental Geography

Learning Objectives

- To define the Environmental Geography.
- To explain the Ecology & Ecosystem.
- To explain the Environmental Disaster.
- To describe the Environmental Hazards.

1.1 Introduction to Environmental Geography: Meaning Definition, Nature & Scope

1.1.1 Environmental Geography

Environmental Geography is the branch of geography that describes and explains the spatial aspects of communications between humans and their social and natural environment.

1.1.1.1 Origins

It requires an understanding of the dynamics of geology, meteorology, hydrology, biogeography, ecology, and geomorphology, as well as the ways in which human societies theoryualize the environment (cultural geography). Thus, to a certain degree, it may be seen as a successor of physical anthropogeography (*Physische Anthropogeographie*) —a term coined by the Vienna Geographer Albrecht Penck in 1924— and geographical cultural or human ecology (Harlan H. Barrows 1923).

1.1.1.2 Focus

The relations between human and physical geography were once more readily apparent than they are today. As the human experience of the world is increasingly mediated by technology, the relationships have often become obscured. Thereby, integrated geography represents a critically important set of analytical tools for assessing the impact of human presence on the environment by measuring the result of human activity on natural landforms and cycles. It hence is considered the third branch of geography, as compared to physical and human geography.

The writings of ancient philosophers made, mention of the relation of the environment geography with the living organisms. The migration of birds from cooler regions during the winter time to the topics, where the climate is warm is a common phenomenon. The growth and development of plants and other organisms are affected by climatic changing conditions.

Herodotus (480 – 425 B.C.) the father of history explained the relation of the physical environment or environment geography to the richness of the delta of the Nile river as an important contributing factor in making the place one of the cradles of ancient civilization.

1.1.2 Nature of Environmental Geography

Geography identifies the theories of place, space, environment, interconnection, sustainability, scale and change, as integral to the development of geographical understanding. These are high-level ideas or ways of thinking that can be applied across the subject to identify a question, guide an investigation, organize information, suggest an explanation or assist decision making.

1.1.2.1 Place

The theory of place is about the significance of places and what they are like. In the Australian Curriculum: Geography, an understanding of the theory of place is developed in the following ways:

- Places are parts of the Earth's surface that are identified and given meaning by people. They may be perceived, experienced, understood and valued differently. They range in size from a part of a room or garden to a major world region. They can be described by their location, shape, boundaries, features and ecological and human characteristics. Some characteristics are tangible, for example, landforms and people, while others are intangible, for example, scenic quality and culture.
- Places are important to our security, identity and sense of belonging, and they provide us with the services and facilities needed to support and enhance our lives. Where people live can influence their wellbeing and opportunities.
- The ecological characteristics of a place are influenced by human actions and the actions of ecological procedures over short to long time periods.
- The human characteristics of a place are influenced by its ecological characteristics and resources, relative location, associations with other places, the culture of its population, the economy of a country, and the decisions and actions of people and organizations over time and at different scales.
- The places in which we live are created, changed and managed by people.
- Each place is unique in its characteristics. As a consequence, the outcomes of similar ecological and socioeconomic procedures vary in different places, and similar problems may require different strategies in different places.
- The sustainability of places may be threatened by a range of factors, for example, natural hazards; climate change; economic, social and technological change; government decisions; conflict; exhaustion of a resource and ecological degradation.

1.1.2.2 Space

The theory of space is about the significance of location and spatial distribution, and ways people organize and manage the spaces that we live in.

- The ecological and human characteristics of places are influenced by their location, but the effects of location and distance from other places on people are being reduced, though unequally, by improvements in transport and communication technologies.
- The individual characteristics of places form spatial distributions, and the analysis of these distributions contributes to geographical understanding. The distributions also have ecological, economic, social and political consequences.
- Spaces are perceived, structured, organized and managed by people, and can be designed and redesigned, to achieve particular purposes.

1.1.2.3 Environment

The theory of environment is about the significance of the environment in human life, and the important interrelationships between humans and the environment.

- The environment is the product of geological, atmospheric, hydrological, geomorphic, edaphic (soil), biotic and human procedures.
- The environment supports and enriches human and other life by providing raw materials and food, absorbing and recycling wastes, maintaining a safe habitat and being a source of enjoyment and inspiration. It presents both opportunities for, and constraints on, human settlement and economic development. The constraints can be reduced but not eliminated by technology and human organization.
- Culture, population density, type of economy, level of technology, values and ecological worldviews influence the different ways in which people perceive, adapt to and use similar environments.
- Management of human-induced ecological change requires an understanding of the causes and consequences of change, and involves the application of geographical theories and techniques to identify appropriate strategies.
- Each type of environment has its specific hazards. The impact of these hazards on people is determined by both natural and human factors, and can be reduced but not eliminated by prevention, mitigation and preparedness.

1.1.2.4 Interconnection

The theory of interconnection emphasizes that no object of geographical study can be viewed in isolation.

- Places and the people and organizations in them are interconnected with other places in a variety of ways. These interassociations have important influences on the characteristics of places and on changes in these characteristics.
- Ecological and human procedures, for example, the water cycle, urbanization or human-induced ecological change, are sets of cause-and-effect interassociations that can operate between and within places. They can sometimes be organized as systems involving networks of interassociations through flows of matter, energy, information and actions.
- Holistic thinking is about seeing the interassociations between phenomena and procedures within and between places.

1.1.2.5 Sustainability

The theory of sustainability is about the capacity of the environment to continue to support our lives and the lives of other living creatures in the future.

- Sustainability is both a goal and a way of thinking about how to progress towards that goal.
- Progress towards ecological sustainability depends on the maintenance or restoration of the ecological functions that sustain all life and human well being (economic and social).
- An understanding of the causes of unsustainability requires a study of the ecological procedures producing the degradation of an ecological function; the human actions that have initiated these procedures; and the attitudinal, demographic, social, economic and political causes of these human actions. These can be analyzed through the framework of human–environment systems.

- There are a variety of contested views on how progress towards sustainability should be achieved and these are often informed by worldviews such as stewardship.

1.1.2.6 Scale

The theory of scale is about the way that geographical phenomena and problems can be examined at different spatial levels.

In the Australian Curriculum: Geography, an understanding of the theory of scale is developed in the following ways:

- Generalizations made and relationships found at one level of scale may be different at a higher or lower level. For example, in studies of vegetation, climate is the main factor at the global scale but the soil and drainage may be the main factors at the local scale.
- Cause-and-effect relationships cross scales from the local to the global and from the global to the local. For example, local events can have global outcomes, such as the effects of local vegetation removal on global climate.

1.1.2.7 Change

The theory of change is about explaining geographical phenomena by investigating how they have developed over time.

- Ecological change can occur over both short and long time frames, and both time scales have interrelationships with human activities.
- Ecological, economic, social and technological change is spatially uneven, and affects places differently.
- An understanding of the current procedures of change can be used to predict changes in the future and to identify what would be needed to achieve preferred and more sustainable futures.

1.1.3 Scope of Environmental Geography

1.1.3.1 Environmental System

- Understand the interaction among four spheres viz. Biosphere, Atmosphere, Hydrosphere and Lithosphere.
- Ecosystem and ecological degradation.
- Structure and components of ecosystem.
- Energy flow in the ecosystem.
- Biogeochemical cycles and circulation of matter in the ecosystem.
- Ecological changes in the ecosystem.
- Ecosystem stability and instability.

1.1.3.2 Man-Environment Relationship in geography:

1. Determinism or Environmentalism

2. Possibilism
3. Neo-determinism

1.1.3.3 Environment policy, Laws & Rules:

1. Agriculture, Industry, Health & Sanitation,
2. Energy & fuel, Water development, Flood
3. Control & Irrigation

1.1.3.4 Global Environment issues:

1. Climate change
2. Global warming & greenhouse effect
3. GHG emission
4. Thinning of the Ozone layer

1.1.3.5 Environment-Man-Society

- Fundamental theories and aspects of environment and its relationships with man and society.
- Meaning, composition and types of environment.
- Relationship between geography and environment, man and nature.
- Man-ecological procedures relationship.
- Theory of ecology.
- Eco-development.
- Ecological ethics and law.
- Ecological modernization.
- Ecological policy and politics.
- Environment and health.

1.1.3.6 Environmental Management

- Sustainable Development.
- Natural Resources Management.
- Disaster Management and Mitigation.
- Energy Policy.
- Ecological Impact Assessment.
- Ecological Monitoring and Planning.
- Ecological Quality Control.
- Ecological Modeling.
- Biovariety Conservation.

1.1.3.7 Significance of Environmental Geography

- It helps to understand the aerial distribution of phenomena.
- To understand the spatial patterns and spatial organization.
- Locational analysis, Regional analysis, Ecological studies.
- To understand the man-environment relationship.
- Find solutions to manage ecological problems.
- Make people aware to protect the environment.

 Proper use of natural resources.
 Sustainable development and biovariety conservation.

1.2 Ecology & Ecosystem; Ecological Hazards

1.2.1 Ecology

Ecology is the systematic study of communications among organisms and their environment, such as the communications organisms have with each other and with their abiotic environment. Topics of importance to ecologists include the variety, distribution, amount (biomass), number (population) of organisms, as well as competition between them within and among ecosystems. Ecosystems are composed of dynamically interacting parts including organisms, the communities they make up, and the non-living components of their environment. Ecosystem procedures, such as primary production, pedogenesis, nutrient cycling, and various niche construction activities, regulate the flux of energy and matter through an environment. These procedures are sustained by organisms with specific life history traits, and the variety of organisms is called biovariety. Biovariety, which refers to the varieties of species, genes, and ecosystems, enhances certain ecosystem services.

Ecology is an interdisciplinary field that includes biology and Earth science. Ancient Greek philosophers such as Hippocrates and Aristotle laid the foundations of ecology in their studies on natural history. Modern ecology transformed into a more rigorous science in the late 19th century. Evolutionary theories of adaptation and natural selection became cornerstones of modern ecological theory. Ecology is not synonymous with environment, environmentalism, natural history, or ecological science. It is closely related to evolutionary biology, genetics, and ethology. An understanding of how biovariety affects the ecological function is an important focus area in ecological studies. Ecologists seek to explain:

- Life procedures, communications and adaptations
- The movement of materials and energy through living communities
- The successional development of ecosystems, and
- The abundance and distribution of organisms and biovariety in the context of the environment.

Ecology is a human science as well. There are many practical applications of ecology in conservation biology, wetland management, natural resource management (Agroecology, agriculture, forestry, Agroforestry, fisheries), city planning (urban ecology), community health, economics, basic and applied science, and human social interaction (human ecology). Organisms and resources compose ecosystems which, in turn, maintain biophysical feedback mechanisms that moderate procedures acting on living (biotic) and nonliving (abiotic) components of the planet. Ecosystems sustain life-supporting functions and produce natural capital like biomass production (food, fuel, fiber and medicine), the regulation of climate, global biogeochemical cycles, water filtration, soil formation, erosion control, flood protection and many other natural features of systematic, historical, economic, or intrinsic value.

1.2.1.1 Integrative levels

The scope of ecology covers a wide array of interacting levels of organization spanning micro-level (e.g., cells) to planetary scale (e.g., biosphere) phenomena. Ecosystems, for example, contain abiotic resources and interacting life forms (i.e., individual organisms that aggregate into populations which aggregate into distinct ecological communities). Ecosystems are dynamic, they do not always follow a linear succession path, but they are always changing, sometimes rapidly and sometimes so slowly that it can take thousands of years for ecological procedures to bring about certain successional stages of a forest. An ecosystem's area can vary greatly, from tiny to vast. A single tree is of little consequence to the classification of a forest ecosystem, but critically relevant to organisms living in and on it. Several generations of an aphid population can exist over the lifespan of a single leaf. Each of those aphids, in turn, support diverse bacterial communities. The nature of associations in ecological communities cannot be explained by knowing the details of each species in isolation, because the evolving pattern is neither revealed nor predicted until the ecosystem is studied as an integrated whole. Some ecological principles, however, do exhibit collective properties where the sum of the components explains the properties of the whole, such as birth rates of a population being equal to the sum of individual births over a designated time frame.

1.2.1.2 Hierarchical ecology

The scale of ecological dynamics can operate like a closed system, such as aphids migrating on a single tree, while at the same time remain open with regard to broader scale influences, such as an atmosphere or climate. Hence, ecologists classify ecosystems hierarchically by analyzing data collected from finer scale units, such as vegetation associations, climate, and soil types, and integrate this information to identify evolving patterns of uniform organization and procedures that operate on local to regional, landscape, and chronological scales.

To structure the study of ecology into a conceptually manageable framework, the biological world is organized into a nested hierarchy, ranging in scale from genes, to cells, to tissues, to organs, to organisms, to species, to populations, to communities, to ecosystems, to biomes, and up to the level of the biosphere. This framework forms a panarchy and exhibits non-linear behaviors; this means that "effect and cause are disproportionate, so that small changes to critical variables, such as the number of nitrogen fixers, can lead to disproportionate, perhaps irreversible, changes in the system properties."

1.2.1.3 Biovariety

Biovariety describes the variety of life from genes to ecosystems and spans every level of biological organization. The term has several interpretations, and there are many ways to index, measure, characterize, and represent its complex organization. Biovariety plays an important role in ecosystem services which by definition maintain and improve human quality of life. Preventing species extinctions is one way to preserve biovariety and that goal rests on techniques that preserve genetic variety, habitat and the ability for species to migrate. Conservation priorities and management techniques require different approaches and considerations to address the full ecological scope of biovariety. Natural capital that supports populations is critical for maintaining ecosystem services and species migration (e.g., riverine fish runs and avian insect control) have been implicated as one mechanism by which those service losses are experienced. An understanding of biovariety has practical applications for species and ecosystem-level conservation planners as they make management recommendations to consulting firms, governments, and industry.

1.2.1.4 Habitat

The habitat of a species describes the environment over which a species is known to occur and the type of community that is formed as a result. More specifically, "habitats can be defined as regions in ecological space that are composed of multiple dimensions, each representing a biotic or abiotic ecological variable; that is, any component or characteristic of the environment related directly (e.g. forage biomass and quality) or indirectly (e.g. elevation) to the use of a location by the animal." For example, a habitat might be an aquatic or terrestrial environment that can be further categorized as a montane or alpine ecosystem. Habitat shifts provide important evidence of competition in nature where one population changes relative to the habitats that most other individuals of the species occupy. For example, one population of a species of tropical lizards (*Tropidurus hispidus*) has a flattened body relative to the main populations that live in open savanna. The population that lives in an isolated rock outcrop hides in crevasses where its flattened body offers a selective advantage. Habitat shifts also occur in the developmental life history of amphibians and in insects that transition from aquatic to terrestrial habitats. Biotope and habitat are sometimes used interchangeably, but the former applies to a community's environment, whereas the latter applies to a species' environment.

Additionally, some species are ecosystem engineers, altering the environment within a localized region. For example, beavers manage water levels by building dams which improves their habitat in a landscape.

1.2.1.5 Niche

Definitions of the niche date back to 1917, but G. Evelyn Hutchinson made conceptual advances in 1957 by introducing a widely adopted definition: "the set of biotic and abiotic conditions in which a species is able to persist and maintain a stable population sizes." The ecological niche is a central theory in the ecology of organisms and is sub-divided into the *fundamental* and the *realized* niche. The fundamental niche is the set of ecological conditions under which a species is able to persist. The realized niche is the set of ecological plus ecological conditions under which a species persists. The Hutchinsonian niche is defined more technically as a "Euclidean hyperspace whose *dimensions* are defined as ecological variables and whose *size* is a function of the number of values that the ecological values may assume for which an organism has *positive fitness*."

Biogeographical patterns and range distributions are explained or predicted through knowledge of a species' traits and niche requirements. Species have functional traits that are uniquely adapted to the ecological niche. A trait is a measurable property, phenotype, or characteristic of an organism that may influence its survival. Genes play an important role in the interplay of development and ecological expression of traits. Resident species evolve traits that are fitted to the selection pressures of their local environment. This tends to afford them a competitive advantage and discourages similarly adapted species from having an overlapping geographic range. The competitive exclusion principle states that two species cannot coexist indefinitely by living off the same limiting resource; one will always outcompete the other. When similarly adapted species overlap geographically, closer inspection reveals subtle ecological differences in their habitat or dietary requirements. Some models and empirical studies, however, suggest that disturbances can stabilize the coevolution and shared niche occupancy of similar species inhabiting species-rich communities. The habitat plus the niche is called the ecotope, which is defined as the full range of ecological and biological variables affecting an entire species.

1.2.1.5.1 Niche construction

Organisms are subject to ecological pressures, but they also modify their habitats. The regulatory feedback between organisms and their environment can affect conditions from local (e.g., a beaver pond) to global scales, over time and even after death, such as decaying logs or silica skeleton deposits from marine organisms. The procedure and theory of ecosystem engineering have also been called niche construction. Ecosystem engineers are defined as: "organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials. In so doing they modify, maintain and create habitats."

The ecosystem-engineering theory has stimulated a new appreciation for the influence that organisms have on the ecosystem and evolutionary procedure. The term "niche construction" is more often used in reference to the under-appreciated feedback mechanism of natural selection imparting forces on the abiotic niche. An example of natural selection through ecosystem engineering occurs in the nests of social insects, including ants, bees, wasps, and termites. There is an evolving homeostasis or homeorhesis in the structure of the nest that regulates, maintains and defends the physiology of the entire colony. Termite mounds, for example, maintain a stable internal temperature through the design of air-conditioning chimneys. The structure of the nests themselves are subject to the forces of natural selection. Moreover, a nest can survive over successive generations, so that progeny inherit both genetic material and a legacy niche that was constructed before their time.

1.2.1.6 Biome

Biomes are larger units of organization that categorize regions of the Earth's ecosystems, mainly according to the structure and composition of vegetation. There are different methods to define the continental boundaries of biomes dominated by different functional types of vegetative communities that are limited in distribution by climate, precipitation, climate and other ecological variables. Biomes include tropical rainforest, temperate broadleaf and mixed forest, temperate deciduous forest, taiga, tundra, hot desert, and polar desert. Other researchers have recently categorized other biomes, such as the human and oceanic microbiomes. To a microbe, the human body is a habitat and a landscape. Microbiomes were discovered largely through advances in molecular genetics, which have revealed a hidden richness of microbial variety on the planet. The oceanic microbiome plays an important role in the ecological biogeochemistry of the planet's oceans.

1.2.1.7 Biosphere

The largest scale of ecological organization is the biosphere: the total sum of ecosystems on the planet. Ecological relationships regulate the flux of energy, nutrients, and climate all the way up to the planetary scale. For example, the dynamic history of the planetary atmosphere's CO_2 and O_2 composition has been affected by the biogenic flux of gases coming from respiration and photosynthesis, with levels fluctuating over time in relation to the ecology and evolution of plants and animals. Ecological theory has also been used to explain self-evolving regulatory phenomena at the planetary scale: for example, the Gaia hypothesis is an example of holism applied in ecological theory. The Gaia hypothesis states that there is an evolving feedback loop generated by the metabolism of living organisms that maintains the temperature of the Earth and atmospheric conditions within a narrow self-regulating range of tolerance.

1.2.1.8 Population ecology

Population ecology studies the dynamics of species populations and how these populations interact with the environment. A population consists of individuals of the same species that live, interact and migrate through the same niche and habitat.

A primary law of population ecology is the Malthusian growth model which states, "a population will grow (or decline) exponentially as long as the environment experienced by all individuals in the population remains stable." Simplified population models usually start with four variables: death, birth, immigration, and emigration.

An example of an introductory population model describes a closed population, such as on an island, where immigration and emigration does not take place. Hypotheses are evaluated with reference to a null hypothesis which states that random procedures create the observed data. In these island models, the rate of population change is described by:

$$\frac{\mathrm{d}N}{\mathrm{d}T} = B - D = bN - dN = (b-d)N = rN,$$

Where *N* is the total number of individuals in the population, *B* is the number of births, *D* is the number of deaths, *b* and *d* are the per capita rates of birth and death, respectively, and *r* is the per capita rate of population change. The formula states that the rate of change in population size (*dN/dT*) is equal to births minus deaths (*B* – *D*).

Using these modelling techniques, Malthus' population principle of growth was later transformed into a model known as the logistic equation:

$$\frac{dN}{dT} = aN\left(1 - \frac{N}{K}\right),$$

Where *N* is the number of individuals measured as biomass density, *a* is the maximum per-capita rate of change, and *K* is the carrying capacity of the population. The formula states that the rate of change in population size (*dN/dT*) is equal to growth (*aN*) that is limited by carrying capacity (1 – *N*/*K*).

Population ecology builds upon these introductory models to further understand demographic procedures in real study populations. Commonly used types of data include life history, fecundity, and survivorship, and these are analyzed using mathematical techniques such as matrix algebra. The information is used for managing wildlife stocks and setting harvest quotas. In cases when the use of null hypotheses is not appropriate, ecologists may adopt different kinds of statistical methods, such as the Akaike information criterion, or use models that can become mathematically complex as "several competing hypotheses are simultaneously confronted with the data."

1.2.1.8.1 Metapopulations and migration

The theory of metapopulations was defined in 1969 as "a population of populations which go extinct locally and recolonize." Metapopulation ecology is another statistical approach that is often used in conservation research. Metapopulation models simplify the landscape into patches of varying levels of quality, and metapopulations are linked by the migratory behavior of organisms. Animal migration is set apart from other kinds of movement because it involves the seasonal departure and return of individuals from a habitat. Migration is also a population-level phenomenon, as with the migration routes followed by plants as they occupied northern post-glacial environments. Plant ecologists use pollen records that accumulate and stratify in wetlands to reconstruct the timing of plant migration and dispersal relative to historic and contemporary climates. These migration routes involved an expansion of the range as plant populations expanded from one area to another. There is a larger taxonomy of movement, such as commuting, foraging, territorial behavior, stasis, and ranging. Dispersal is usually distinguished from migration because it involves the one way permanent movement of individuals from their birth population into another population.

In metapopulation terminology, migrating individuals are classed as emigrants (when they leave a region) or immigrants (when they enter a region), and sites are classed either as sources or sinks. A site is a generic term that refers to places where ecologists sample populations, such as ponds or defined sampling areas in a forest. Source patches are productive sites that generate a seasonal supply of juveniles that migrate to other patch locations. Sink patches are unproductive sites that only receive migrants; the population at the site will disappear unless rescued by an adjacent source patch or ecological conditions become more favorable. Metapopulation models examine patch dynamics over time to answer questions about spatial and demographic ecology. The ecology of metapopulations is a dynamic procedure of extinction and colonization. Small patches of lower quality (i.e., sinks) are maintained or rescued by a seasonal influx of new immigrants. A dynamic metapopulation structure evolves from year to year, where some patches are sinks in dry years and are sources when conditions are more favorable. Ecologists use a mixture of computer models and field studies to explain the metapopulation structure.

1.2.1.9 Community ecology

Community ecology is the study of the communications among a collection of species that inhabit the same geographic area. Research in community ecology might measure primary production in a wetland in relation to decomposition and consumption rates. This requires an understanding of the community associations between plants (i.e., primary producers) and the decomposers (e.g., fungi and bacteria), or the analysis of predator-prey dynamics affecting amphibian biomass. Food webs and trophic levels are two widely employed conceptual models used to explain the linkages among species.

1.2.1.10 Ecosystem ecology

Ecosystems are habitats within biomes that form an integrated whole and a dynamically responsive system having both physical and biological complexes. The underlying theory can be traced back to 1864 in the published work of George Perkins Marsh ("Man and Nature"). Within an ecosystem, organisms are linked to the physical and biological components of their environment to which they are adapted. Ecosystems are complex adaptive systems where the interaction of life procedures forms self-organizing patterns across different scales of time and space. Ecosystems are broadly categorized as terrestrial, freshwater, atmospheric, or marine. Differences stem from the nature of the unique physical environments that shapes the biovariety within each. A more recent addition to ecosystem ecology are technoecosystems, which are affected by or primarily the result of human activity.

1.2.1.11 Food webs

A food web is the archetypal ecological network. Plants capture solar energy and use it to synthesize simple sugars during photosynthesis. As plants grow, they accumulate nutrients and are eaten by grazing herbivores, and the energy is transferred through a chain of organisms by consumption. The simplified linear feeding pathways that move from a basal trophic species to a top consumer is called the food chain. The larger interlocking pattern of food chains in an ecological community creates a complex food web. Food webs are a type of theory map or a heuristic device that is used to illustrate and study pathways of energy and material flows. Food webs are often limited relative to the real world. Complete empirical measurements are generally restricted to a specific habitat, such as a cave or a pond, and principles gleaned from food web microcosm studies are extrapolated to larger systems. Feeding relations require extensive investigations into the gut contents of organisms, which can be difficult to decipher, or stable isotopes can be used to trace the flow of nutrient diets and energy through a food web. Despite these limitations, food webs remain a valuable tool in understanding community ecosystems.

Food webs exhibit principles of ecological emergence through the nature of trophic relationships: some species have many weak feeding relations (e.g., omnivores) while some are more specialized with fewer stronger feeding relations (e.g., primary predators). Theoretical and empirical studies identify non-random evolving patterns of few strong and many weak linkages that explain how ecological communities remain stable over time. Food webs are composed of subgroups where members of a community are linked by strong communications, and the weak communications occur between these subgroups. This increases food web stability. Step by step lines or relations are drawn until a web of life is illustrated.

1.2.1.12 Trophic levels

A trophic level is "a group of organisms acquiring a considerable majority of its energy from the adjacent level nearer the abiotic source." Relations in food webs primarily connect feeding relations or trophism among species. Biovariety within ecosystems can be organized into trophic pyramids, in which the vertical dimension represents feeding relations that become further removed from the base of the food chain up toward top predators, and the horizontal dimension represents the abundance or biomass at each level. When the relative abundance or biomass of each species is sorted into its respective trophic level, they naturally sort into a 'pyramid of numbers'.

Species are broadly categorized as autotrophs (or primary producers), heterotrophs (or consumers), and Detritivores (or decomposers). Autotrophs are organisms that produce their own food (production is greater than respiration) by photosynthesis or chemosynthesis. Heterotrophs are organisms that must feed on others for nourishment and energy (respiration exceeds production). Heterotrophs can be further sub-divided into different functional groups, including primary consumers (strict herbivores), secondary consumers (carnivorous predators that feed exclusively on herbivores) and tertiary consumers (predators that feed on a mix of herbivores and predators). Omnivores do not fit neatly into a functional category because they eat both plant and animal tissues. It has been suggested that omnivores have a greater functional influence as predators, because compared to herbivores they are relatively inefficient at grazing.

Trophic levels are part of the holistic or complex systems view of ecosystems. Each trophic level contains unrelated species that are grouped together because they share common ecological functions, giving a macroscopic view of the system. While the notion of trophic levels provides insight into energy flow and top-down control within food webs, it is troubled by the prevalence of omnivory in real ecosystems. This has led some ecologists to "reiterate that the notion that species clearly aggregate into discrete, homogeneous trophic levels is fiction." Nonetheless, recent studies have shown that real trophic levels do exist, but "above the herbivore trophic level, food webs are better characterized as a tangled web of omnivores."

1.2.1.13 Keystone species

A keystone species is a species that are connected to a disproportionately large number of other species in the food-web. Keystone species have lower levels of biomass in the trophic pyramid relative to the importance of their role. The many associations that a keystone species holds means that it maintains the organization and structure of entire communities. The loss of a keystone species results in a range of dramatic cascading effects that alters trophic dynamics, other food web associations, and can cause the extinction of other species.

Sea otters (*Enhydra lutris*) are commonly cited as an example of a keystone species because they limit the density of sea urchins that feed on kelp. If sea otters are removed from the system, the urchins graze until the kelp beds disappear and this has a dramatic effect on community structure. Hunting of sea otters, for example, is thought to have indirectly led to the extinction of the Steller's Sea Cow (*Hydrodamalis gigas*). While the keystone species theory has been used extensively as a conservation tool, it has been criticized for being poorly defined from an operational stance. It is difficult to experimentally determine what species may hold a keystone role in each ecosystem. Furthermore, the food web theory suggests that keystone species may not be common, so it is unclear how generally the keystone species model can be applied.

1.2.1.14 Ecological complexity

Complexity is understood as a large computational effort needed to piece together numerous interacting parts exceeding the iterative memory capacity of the human mind. Global patterns of biological variation are complex. This Biocomplexity stems from the interplay among ecological procedures that operate and influence patterns at different scales that grade into each other, such as transitional areas or ecotones spanning landscapes. Complexity stems from the interplay among levels of biological organization as energy and matter are integrated into larger units that superimpose onto the smaller parts. "What were wholes on one level become parts with a higher one." Small scale patterns do not necessarily explain large scale phenomena, otherwise captured in the expression (coined by Aristotle) 'the sum is greater than the parts'.

"Complexity in ecology is of at least six distinct types: spatial, temporal, structural, procedural, behavioral, and geometric." From these principles, ecologists have identified evolving and self-organizing phenomena that operate at different ecological scales of influence, ranging from molecular to planetary, and these require different explanations at each integrative level. Ecological complexity relates to the dynamic resilience of ecosystems that transition to multiple shifting steady-states directed by random fluctuations of history. Long-term ecological studies provide important track records to better understand the complexity and resilience of ecosystems over long temporal and broader spatial scales. These studies are managed by the International Long Term Ecological Network (LTER). The longest experiment in existence is the Park Grass Experiment, which was initiated in 1856. Another example is the Hubbard Brook study, which has been in operation since 1960.

1.2.1.15 Holism

Holism remains a critical part of the theoretical foundation in contemporary ecological studies. Holism addresses the biological organization of life that self-organizes into layers of evolving whole systems that function according to nonreducible properties. This means that higher order patterns of a whole functional system, such as an ecosystem, cannot be predicted or understood by a simple summation of the parts. "New properties emerge because the components interact, not because the basic nature of the components is changed."

Ecological studies are necessarily holistic as opposed to reductionist. Holism has three systematic meanings or uses that identify with ecology: 1) the mechanistic complexity of ecosystems, 2) the practical description of patterns in quantitative reductionist terms where correlations may be identified but nothing is understood about the causal relations without reference to the whole system, which leads to 3) a metaphysical hierarchy whereby the causal relations of larger systems are understood without reference to the smaller parts. Systematic holism differs from the mysticism that has appropriated the same term. An example of metaphysical holism is identified in the trend of increased exterior thickness in shells of different species. The reason for a thickness increase can be understood through reference to principles of natural selection via predation without need to reference or understand the Biomolecular properties of the exterior shells.

1.2.1.16 Relation to evolution

Ecology and evolution are considered sister disciplines of the life sciences. Natural selection, life history, development, adaptation, populations, and inheritance are examples of theories that thread equally into ecological and evolutionary theory. Morphological, behavioral and genetic traits, for example, can be mapped onto evolutionary trees to study the historical development of a species in relation to their functions and roles in different ecological circumstances. In this framework, the analytical tools of ecologists and evolutionists overlap as they organize, classify and investigate life through common systematic principals, such as phylogenetic or the Linnaean system of taxonomy. The two disciplines often appear together, such as in the title of the journal *Trends in Ecology and Evolution*. There is no sharp boundary separating ecology from evolution and they differ more in their areas of applied focus. Both disciplines discover and explain evolving and unique properties and procedures operating across different spatial or temporal scales of organization. While the boundary between ecology and evolution is not always clear, ecologists study the abiotic and biotic factors that influence evolutionary procedures, and evolution can be rapid, occurring on ecological timescales as short as one generation.

1.2.1.17 Behavioral ecology

All organisms are motile to some extent. Even plants express complex behavior, including memory and communication. Behavioral ecology is the study of an organism's behavior in its environment and its ecological and evolutionary implications. Ethology is the study of observable movement or behavior in animals. This could include investigations of motile sperm of plants, mobile phytoplankton, zooplankton swimming toward the female egg, the cultivation of fungi by weevils, the mating dance of a salamander, or social gatherings of amoeba.

Adaptation is the central unifying theory in behavioral ecology. Behaviors can be recorded as traits and inherited in much the same way that eye and hair colour can. Behaviors can evolve by means of natural selection as adaptive traits conferring functional utilities that increases reproductive fitness.

Predator-prey communications are an introductory theory into food-web studies as well as behavioral ecology. Prey species can exhibit different kinds of behavioral adaptations to predators, such as avoid, flee or defend. Many prey species are faced with multiple predators that differ in the degree of danger posed. Be adapted to their environment and face predatory threats, organisms must stable their energy budgets as they invest in different aspects of their life history, such as growth, feeding, mating, socializing, or modifying their habitat. Hypotheses posited in behavioral ecology are generally based on adaptive principles of conservation, optimization or efficiency. For example, "[t] he threat-sensitive predator avoidance hypothesis predicts that the prey should assess the degree of threat posed by different predators and match their behavior according to current levels of risk" or "[t] he optimal flight initiation distance occurs where expected post encounter fitness is maximized, which depends on the prey's initial fitness, benefits obtainable by not fleeing, energetic escape costs, and expected fitness loss due to predation risk."

Elaborate sexual displays and posturing are encountered in the behavioral ecology of animals. The birds of paradise, for example, sing and display elaborate ornaments during courtship. These displays serve a dual purpose of signalling healthy or well-adapted individuals and desirable genes. The displays are driven by sexual selection as an advertisement of quality of traits among the suitors.

1.2.1.18 Biogeography

Biogeography is the comparative study of the geographic distribution of organisms and the corresponding evolution of their traits in space and time. The *Journal of Biogeography* was established in 1974. Biogeography and ecology share many of their disciplinary roots. For example, the theory of island biogeography, published by the mathematician Robert MacArthur and ecologist Edward O. Wilson in 1967 is considered one of the fundamentals of ecological theory.

Biogeography has a long history in the natural sciences concerning the spatial distribution of plants and animals. Ecology and evolution provide the explanatory context for biographical studies. Biogeographical patterns result from ecological procedures that influence range distributions, such as migration and dispersal. And from historical procedures that split populations or species into different areas. The biogeographic procedures that result in the natural splitting of species explains much of the modern distribution of the Earth's biota. The splitting of lineages in a species is called vicariance biogeography and it is a sub-discipline of biogeography. There are also practical applications in the field of biogeography concerning ecological systems and procedures. For example, the range and distribution of biovariety and invasive species responding to climate change is a serious concern and active area of research in the context of global warming.

1.2.1.19 Molecular ecology

The important relationship between ecology and genetic inheritance predates modern techniques for molecular analysis. Molecular ecological research became more feasible with the development of rapid and accessible genetic technologies, such as the polymerase chain reaction (PCR). The rise of molecular technologies and influx of research questions into this new ecological field resulted in the publication *Molecular Ecology* in 1992. Molecular ecology uses various analytical techniques to study genes in an evolutionary and ecological context. In 1994, John Avise also played a leading role in this area of science with the publication of his book, *Molecular Markers, Natural History and Evolution*. Newer technologies opened a wave of genetic analysis into organisms once difficult to study from an ecological or evolutionary standpoint, such as bacteria, fungi and nematodes. Molecular ecology engendered a new research paradigm for investigating ecological questions considered otherwise intractable. Molecular investigations revealed previously obscured details in the tiny intricacies of nature and improved resolution into probing questions about behavioral and biogeographical ecology. For example, molecular ecology revealed promiscuous sexual behavior and multiple male partners in tree swallows previously thought to be socially monogamous. In a biographical context, the marriage between genetics, ecology and evolution resulted in a new sub-discipline called phylogeography.

1.2.1.20 Human ecology

Ecology is as much a biological science as it is a human science. Human ecology is an interdisciplinary investigation into the ecology of our species. "Human ecology may be defined: (1) from a bio-ecological standpoint as the study of man as the ecologically dominant in plant and animal communities and systems; (2) from a bio-ecological standpoint as simply another animal affecting and being affected by his physical environment; and (3) as a human being, somehow different from animal life in general, interacting with physical and modified environments in a distinctive and creative way. A truly interdisciplinary human ecology will most likely address itself to all three." The term was formally introduced in 1921, but many sociologists, geographers, psychologists, and other disciplines were important in human relations to natural systems centuries prior, especially in the late 19th century.

The ecological complexities human beings are facing through the technological transformation of the planetary biome has brought on the Anthropocene. The unique set of circumstances has generated the need for a new unifying science called coupled human and natural systems that builds upon, but moves beyond the field of human ecology. Ecosystems tie into human societies through the critical and all encompassing life-supporting functions they sustain. In recognition of these functions and the incapability of traditional economic valuation methods to see the value in ecosystems, there has been a surge of importance in the social-natural capital, which provides the means to put a value on the stock and use of information and materials stemming from ecosystem goods and services. Ecosystems produce, regulate, maintain, and supply services of critical necessity and beneficial to human health (cognitive and physiological), economies, and they even provide an information or reference function as a living library giving opportunities for science and cognitive development in children engaged in the complexity of the natural world. Ecosystems relate importantly to human ecology as they are the ultimate base foundation of global economics as every commodity and the capacity for exchange ultimately stems from the ecosystems on Earth.

1.2.1.20 Physical environments

1.2.1.20.1 Water

Diffusion of carbon dioxide and oxygen is approximately 10,000 times slower in water than in air. When soils are flooded, they quickly lose oxygen, becoming hypoxic (an environment with O_2 concentration below 2 mg/liter) and eventually completely anoxic where anaerobic bacteria thrive among the roots. Water also influences the intensity and spectral composition of light as it reflects off the water surface and submerged particles. Aquatic plants exhibit a wide variety of morphological and physiological adaptations that allow them to survive, compete and diversify in these environments. For example, their roots and stems contain large air spaces (aerenchyma) that regulate the efficient transportation of gases (for example, CO_2 and O_2) used in respiration and photosynthesis. Salt water plants (halophytes) have additional specialized adaptations, such as the development of special organs for shedding salt and osmoregulating their internal salt (NaCl) concentrations, to live in estuarine, brackish, or oceanic environments. Anaerobic soil microorganisms in aquatic environments use nitrate, manganese ions, ferric ions, sulfate, carbon dioxide and some organic compounds; other microorganisms are facultative anaerobes and use oxygen during respiration when the soil becomes drier. The activity of soil microorganisms and the chemistry of the water reduces the oxidation-reduction potentials of the water. Carbon dioxide, for example, is reduced to methane (CH_4) by methanogenic bacteria. The physiology of fish is also specially adapted to compensate for ecological salt levels through osmoregulation. Their gills form electrochemical gradients that mediate salt excretion in salt water and uptake in fresh water.

1.2.1.20.2 Gravity

The shape and energy of the land is importantly affected by gravitational forces. On a large scale, the distribution of gravitational forces on the earth is uneven and influences the shape and movement of tectonic plates as well as influencing geomorphic proceduree s such as orogeny and erosion. These forces govern many of the geophysical properties and distributions of ecological biomes across the Earth. On the organismal scale, gravitational forces provide directional cues for plant and fungal growth (gravitropism), orientation cues for animal migrations, and influence the biomechanics and size of animals. Ecological traits, such as allocation of biomass in trees during growth are subject to mechanical failure as gravitational forces influence the position and structure of branches and leaves. The cardiovascular systems of animals are functionally adapted to overcome pressure and gravitational forces that change according to the features of organisms (e.g., height, size, shape), their behavior (e.g., diving, running, flying), and the habitat occupied (e.g., water, hot deserts, cold tundra).

1.2.1.20.3 Pressure

Climatic and osmotic pressure places physiological constraints on organisms, especially those that fly and respire at high altitudes, or dive to deep ocean depths. These constraints influence vertical limits of ecosystems in the biosphere, as organisms are physiologically sensitive and adapted to atmospheric and osmotic water pressure differences. For example, oxygen levels decrease with decreasing pressure and are a limiting factor for life at higher altitudes. Water transportation by plants is another important ecophysiological parameter affected by osmotic pressure gradients. Water pressure in the depths of the oceans requires that organisms adapt to these conditions. For example, diving animals such as whales, dolphins and seals are specially adapted to deal with changes in sound due to water pressure differences.

Differences between hagfish species provide another example of adaptation to deep-sea pressure through specialized protein adaptations.

1.2.1.20.4 Wind and turbulence

Turbulent forces in the air and water affect the environment and ecosystem distribution, form and dynamics. On a planetary scale, ecosystems are affected by circulation patterns in the global trade winds. Wind power and the turbulent forces it creates can influence heat, nutrient, and biochemical profiles of ecosystems. For example, the wind running over the surface of a lake creates turbulence, mixing the water column and influencing the ecological profile to create thermally layered zones, affecting how fish, algae, and other parts of the aquatic ecology are structured. Wind speed and turbulence also influence evapotranspiration rates and energy budgets in plants and animals. Wind speed, temperature and moisture content can vary as winds travel across different land features and elevations. For example, the westerlies come into contact with the coastal and interior mountains of western North America to produce a rain shadow on the leeward side of the mountain. The air expands and moisture condenses as the winds increase in elevation; this is called orographic lift and can cause precipitation. This ecological procedure produces spatial divisions in biovariety, as species adapted to wetter conditions are range-restricted to the coastal mountain valleys and unable to migrate across the xeric ecosystems (e.g., of the Columbia Basin in western North America) to intermix with sister lineages that are segregated to the interior mountain systems.

1.2.1.20.5 Fire

Plants convert carbon dioxide into biomass and emit oxygen into the atmosphere. Approximately 350 million years ago (at the end of the Devonian period), the amount of photosynthesis brought the concentration of atmospheric oxygen above 17%, which allowed combustion to occur. Fire releases CO_2 and converts fuel into ash and tar. Fire is an important ecological parameter that raises many issues pertaining to its control and suppression. While the issue of fire in relation to ecology and plants has been recognized for a long time, Charles Cooper brought attention to the issue of forest fires in relation to the ecology of forest fire suppression and management in the 1960s.

Native North Americans were among the first to influence fire regimes by controlling their spread near their homes or by lighting fires to stimulate the production of herbaceous foods and basketry materials. Fire creates a heterogeneous ecosystem age and canopy structure, and the altered soil nutrient supply and cleared canopy structure opens new ecological niches for seedling establishment. Most ecosystems are adapted to natural fire cycles. Plants, for example, are equipped with a variety of adaptations to deal with forest fires. Some species (e.g., *Pinus halepensis*) cannot germinate until after their seeds have lived through a fire or been exposed to certain compounds from smoke. Environmentally triggered the germination of seeds is called serotiny. Fire plays a major role in the persistence and resilience of ecosystems.

1.2.2 Ecosystem

An ecosystem is a portmanteau word - that is, a word made by jamming two other words together. It originated as a shorthand way of referring to an ecological system, and is now the preferred term.

An ecosystem is simply an easy way to refer to all the life forms (plant and animal) in a cohesive, relatively independent area, and their relationship to one another. In a perfect world, an ecosystem is stable. That is, the predator species keep the prey species' population in check without completely destroying them, and Plantlife remains varied without one type predominating and crowding out the rest.

Ecosystems are rarely in stable, and this is often causing for alarm. For example, polluted runoff from a factory can affect marine life in a lake, causing the fish population to plummet. This destabilizes the entire surrounding ecosystem, and birds and animals that prey on the fish either die off or migrate to areas with more food.

Attempting to counteract damage to an ecosystem requires a complete understanding of all the interrelationships between plants, animals and the atmosphere in the system. Since such perfect understanding is rarely possible, unintended consequences are often the result.

For example, the US government recommended in the 1930s that farmers in the south plant kudzu as a ground cover to help prevent erosion. Now kudzu is a nuisance plant and many thousands of hours a year are logged in trying to keep the kudzu from taking over, damaging roadways and buildings and choking out other plant species. A similar takeover of a non-native species are seen in the rabbit problem in Australia. Rabbits have no natural predator native to Australia, so when they were introduced in the nineteenth century, they proliferated like, well, rabbits, to the point where their effects on the ecosystem, particularly farmland, has been devastating.

In nature, no ecosystem can be said to be independent of neighboring ecosystems or indeed, the global ecosystem, since ecosystems are open and plants and animals can move between them. All ecosystems are affected by planet-wide trends that affect the atmosphere, such as pollution and global warming.

One attempt to study an ecosystem in isolation was Biosphere 2, an airtight enclosure that tried to duplicate an ecosystem instable. Although the experiment was not successful - they were unable to maintain oxygen levels high enough for human health without importing it - the experiment did make clear how fragile the stability of an ecosystem is and how dangerous it can be to severely damage the ecosystem of the entire earth.

1.2.2.1 Ecosystem Model

An ecosystem model is a representation of an ecosystem shown in mathematical form. Such models are used in theoretical ecology to help ecologists study existing ecosystems and predict what might happen given certain conditions. An ecosystem is incredibly complex, so an ecosystem model generally must simplify the system by focusing only on specific parts.

Ecosystems are biological environments. They include all living creatures in a particular area as well as the physical characteristics of that area that might affect or be used by the organisms in it. These could be such things as air, water or amount of sunlight. The model must also take into account the size of the environment being studied since this may have an effect on the organisms in it.

In order to create a workable mathematical model, an ecologist must simplify the ecosystem he or she is trying to study. This can be done by focusing on a limited number of species or groups that share certain traits. These traits could be behavioral, biochemical or physical.

Once the ecologist has isolated the organisms of importance, he or she creates a food chain for them. A food chain is a representation of predator-prey relationships. For example, if the animal of importance is the coyote, the food chain might show that the coyote eats rabbits, which eat ground level vegetation. The coyotes, the rabbits and the vegetation will all become elements in the ecosystem model.

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The elements in the ecosystem model are then linked together using mathematical functions that describe their relationships. Again the complexity of an ecosystem presents a problem for the ecologist. It is difficult to observe what actual affect the consumption of a single rabbit will have on the coyote population, so ecologists use statistics, observation and other methods to arrive at an educated guess. Mathematical functions can be adjusted as real events in the ecosystem prove or disprove the accuracy of the ecosystem model.

A classic ecosystem model studied by ecology students is the predator-prey model created in the mid 1920s. It was created independently by two scientists in the space of one year: US mathematician, chemist and statistician Alfred J Lotka and Italian mathematician and physicist Vito Volterra. Their model uses a pair of differential equations to represent predators and prey. Though originally used to describe fluctuations in shark and fish populations in the Adriatic Sea, the model works as a general description of the predator-prey relationship.

1.2.3 Environmental Hazards

In any given day, humans may be exposed to multiple ecological hazards. These hazards can include common household, outdoor or workplace ecological factors. The most common of these ecological concerns are chemical or biological in nature.

Most households or workplaces contain chemicals in the form of cleaning agents, drinking water additives, chemicals in clothing and furniture as well as the agents that are imbedded in building materials like drywall, carpets and paint. In some buildings, people are exposed to health hazards as a result of heating or air conditioning systems. While limited amounts of these chemicals generally stay within safe limits and have no adverse affect on humans; long-term exposure can result in sensitivity reactions in adults and serious problems with children’s health.

In addition to chemicals, people are exposed to many biological agents in the environment. Outside, we can be exposed to cancer-causing sunlight, air and noise pollution, pesticides and even naturally-occurring chemical agents that can cause allergic reactions. Inside, people can be exposed to things like germs and illnesses spread by human contact or artificial additives in food products. Biological agents are responsible for many of the chronic health problems seen today in adults and children.

As for commercial buildings or areas where new construction is occurring, generally it is up to a government administered ecological agency to provide health inspection services. This helps to identify and reduce any possible ecological hazards in order to reduce illness or injury to people who must be in the vicinity. This is especially important to prevent people from falling victim to ecological hazards commonly found in construction materials like paint, treated wood, fiberglass and carpets.

When people hear the phrase “ecological hazard,” they most often think of major commercial-scale disasters such as oil spills or nuclear waste leaks that require years of cleanup. While these events are certainly devastating to the areas in which they occur, it's important to remember that there are many ecological hazards in homes and businesses around the world that wreak havoc on people's lives. With a level of awareness and education, these factors can be managed properly in order to minimize their effect on humans.

With better lifestyle choices, we can prevent and limit exposure to ecological hazards by using natural products to clean with, drinking filtered water, eating organically produced foods and using caution when in environments that may contain a higher than normal level of contaminants. Using the guidelines set forth by the ecological health agencies in the region is a good way to start making changes that will lower the ecological impact these hazards have on daily life.

1.3 Environmental Disaster & Stress

1.3.1 Environmental Disaster

An ecological disaster is defined as a specific event caused by human activity that results in a seriously negative effect on the environment. Sometimes a natural calamity can become an ecological calamity, but that is a topic to be discussed elsewhere.

In most cases ecological calamities are caused by human error, accident, lack of foresight, corner cutting during industrial procedures, greed, or by simple incompetence. In other words without some kind of human intervention they would never have happened. They are also often characterized by firm authoritative denials that anything serious has even happened.

Lack of foresight is a common cause of an ecological calamity. In agriculture a classic example of is the increasing salinity of soils in hot climates. With the need to produce more food, a warm climate seems ideal for European-style agriculture, once the existing vegetation has been cleared. The one proviso is that there must be plenty of water. Irrigation projects and deep wells are usually the answer, but as has been found in Australia, if this is not properly managed, salination can result and the land becomes effectively useless.

A further example of a catastrophic and misguided interference with nature resulted in the dust bowls that hit North America in the 1930s. The fertile soil seemed ideal for intensive agriculture, but a combination of deep ploughing and a lack of crop rotation weakened the soil structure. Following years of drought, high winds simply removed all the topsoil and millions of acres of once fertile farmland became a virtual desert.

Another unforeseen agricultural calamity was Mao Zedong's 1958 decree to eliminate sparrows. It was considered that because sparrows ate grain seeds they were robbing the people of the fruits of their labor. The campaign was very successful that it cleared the way for swarms of locusts to descend on the farms. Crops were decimated, leading to a famine that resulted in the deaths of 38 million people.

Introducing alien species can be just as disastrous as eliminating native ones. This has been the case in Australia when in 1859 12 imported English wild rabbits were released so that a local settler could go hunting. In the course of time they multiplied and it is estimated that even after serious efforts to control them, the Australian rabbit populations are still between 200 and 300 million.

As well as being responsible for the loss of vast acreages of agricultural crops and grazing land, rabbits are suspected of being the most important known factor in species loss in Australia, killing young trees by eating the bark at the base of the trunk. They are also responsible for serious erosion as they eat native plants, leaving the topsoil exposed.

It is very easy to upset the fragile stable of nature. In June 1918 a steamship ran aground on a Pacific Island and while it was stranded, Black Rats escaped and got ashore. Here they thrived, causing the extinction of several of the island's endemic birds and other fauna. They also raided the crops of the islanders, particularly the seeds of the Kentia Palm, which was the islanders' only export commodity.

In an effort to control the rats, Masked Owls were introduced but this simply compounded the ecological calamity. By introducing yet another predator to the ecosystem, the result was that many of the remaining sea birds were simply wiped out as breeding species.

Industrial pollution has been the cause of so many ecological calamities that it is impossible to list them all. One of the most serious was the Bhopal calamity of December 1984 when a leak of methyl isocyanate resulted in at least 22,000 deaths plus various genetic diseases that will continue for generations. The chief causes of this calamity were negligent, corruption and the complete disregard of safety standards.

In West Africa the Niger Delta covers 20,000 km^2 within wetlands of 70,000 km^2, formed primarily by sediment deposition. It is home to some 20 million people from 40 different ethnic groups. Its floodplain makes up 7.5% of Nigeria's total land mass and is the third-largest drainage basin in Africa.

Its ecosystem contains one of the highest concentrations of biovariety on the planet. In addition to supporting a vast range of flora and fauna, there is arable terrain that can sustain a wide variety of crops, tropical forests and more species of freshwater fish than any other ecosystem in West Africa.

Unfortunately for the Niger Delta, oil was discovered in the region. Since drilling began in 1976 there has been a complete lack of concern by the Nigerian Government or the oil operators to exert any control of the ecological problems associated with the industry.

The Nigerian National Petroleum Corporation admits that every year as a result of around 300 individual spells, nearly 2,300 cubic meters of petroleum are jettisoned into the environment. However, this does not take account of so-called "minor" spills and one estimate puts the total spillage between 1960 and 1997 as upwards of 100 million barrels (16 million cubic meters).

A major reason for these spills is simply the result of poor maintenance. Pipelines are old and corroded and although they have an estimated lifespan of about 15 years, many have been in use for about 25. Leaking pipes and the use of old and corroded tankers account for 50% of all spills.

Understandably there has been a major impact on the ecosystem. Enormous tracts of mangrove forest have been destroyed along with most of the flora and fauna that were once found there.

The dumping of waste is obviously a serious issue and international regulations put strict controls on this. Unfortunately there will always be unscrupulous people who will try to get around the regulations.

A classic example occurred in 2006 when a Panama-registered ship offloaded 500 tonnes of toxic waste at the Ivory Coast port of Abidjan. The company concerned apparently wanted to avoid paying the 1,000 euros per cubic meter disposal charge it would have to pay in Holland.

The waste, that was dumped at 12 sites in and around the city was later discovered to contain a mixture of fuel, caustic soda and hydrogen sulphide. This lethal cocktail gave off toxic gas and caused burns to the lungs and skin, in addition to severe headaches and vomiting and is said to have caused 17 deaths and made dozens seriously ill.

The company involved originally denied all responsibility, claiming that the waste was simply dirty water. It was only after some investigative journalism by the BBC that the full facts eventually came to light.

Nuclear accidents can have serious ecological effects. Prior to 2011 the 1986 Chernobyl calamity would probably have been regarded as the most serious after an enormous explosion sent radioactive ash into the atmosphere covering most of Northern Europe, along with Belarus, Ukraine and Russia. 350,000 people had to be resettled.

Then in 2011 came the Fukushima 1 accident in Japan when a tremor followed by a tsunami hit the nuclear plant. The tremor knocked out the public electricity supply that powered the pumping of water to cool the reactors. Shortly after the tremor a tsunami destroyed the emergency back-up generators that were due to start up when the public electricity supply failed. It was then realized that the designers had failed to take this possibility into account.

As a result a catastrophic situation developed and 14,000 people had to be evacuated from the immediate area. After several weeks a number of brave workers, struggling in appalling conditions, managed to bring the situation under control, but as with so many ecological calamity, once again official information was misleading, sketchy, or simply non-existent.

An ecological calamity is usually caused by some form human action, or some form of human negligence. A classic example is with climate change. Vast amounts of greenhouse gas are currently being released into the Earth's atmosphere, potentially doing untold harm to our environment by speeding up global warming. At the same time people are completely ignoring the warning signs and shutting their minds to the consequences that lie ahead.

We don't know what these consequences will be, but they are not likely to be pleasant. The world seems to be on course for what is likely to be the worst ecological calamity of all time. There is still time to slow the procedure down, but it will require swift and worldwide action.

1.4 Classification of Environmental Hazards

Oil spills and nuclear waste leaks aren't the only ecological hazards we need to worry about. Similar hazards are also endangering lives in homes and businesses around the world. With a little awareness and education, these ecological hazards can be managed properly in order to minimize their effect on humans.

1.4.1 **Air and water quality**

Did you know that there is a growing belief that climate change has an impact on air and water quality and consequently our health and well being? Chemical contaminants released into the air can have the same effect as those released on the ground or in the water: they can persist in the environment and accumulate in the tissues of plants and animals, moving through the food chain and affecting growth and reproduction in living creatures of all sizes.

1.4.2 Biological threats

Biological agents have the ability to adversely affect human health in a variety of ways, ranging from relatively mild, allergic reactions to serious medical conditions, even death. Here you'll find fact sheets and technical and regulatory information about some of the most virulent and prevalent biological agents.

1.4.3 Chemical agents

Chemical agents are chemical compounds that have harmful effects on human health. There are a number of different types of chemical agents, and a range of uses for these compounds, from crowd control to chemical warfare. Here is a list of chemical agents by category from the Center for Disease Control, along with definitions, clinical description, lab criteria for diagnosis, and case classification.

1.4.4 Hazardous materials and environmental emergencies

Learn how to prepare, prevent, and protect yourself and others from dangerous materials and ecological emergencies, such as an accident scene where hazardous materials may have been spilled.

1.4.5 **Household hazardous materials**

1.4.5.1 Lead information

Lead is a toxic metal that was used for many years in paint and other products found in and around our homes. Lead also can be emitted into the air from industrial sources and leaded aviation gasoline, and lead can enter drinking water from plumbing materials. Lead may cause a range of health effects, from behavioral problems and learning disabilities, to seizures and death. Children six years old and under are most at risk.

1.4.5.2 Mercury

When a product containing mercury breaks and the mercury is spilled (as sometimes happens when it's not disposed of properly), the exposed mercury can evaporate and become an invisible, odorless toxic vapor that can even adversely affect our fish supply. Check out these products and learn more about how to safely use and store them, and properly manage their disposal.

1.4.6 Nuclear and radiological threats

Some radioactive materials that are not used properly can pose unacceptable risks to people and the environment. Potassium iodide (also called KI) is a salt of stable (not radioactive) iodine. Stable iodine is an important chemical needed by the body to make thyroid hormones; however, taking KI may be harmful for some people because of the high levels of iodine in this medicine. Learn more about the possible risks and side effects of both here.

1.4.7 Natural hazards

Natural hazards such as flood, fire, tremor , tornado, and windstorms affect hundreds of people in Massachusetts every year. We need to know what our risks are from natural hazards and take sensible precautions to protect ourselves, our families, and our communities.

1.5 Environmental Movement

1.5.1 Chipko

In the 1970s, an organized resistance to the destruction of forests spread throughout India and came to be known as the Chipko movement. The name of the movement comes from the word 'embrace', as the villagers hugged the trees, and prevented the contractors' from felling them.

Not many people know that over the last few centuries many communities in India helped save nature. One such is the Bishnoi community of Rajasthan. The original 'Chipko movement' was started around 260 years back in the early part of the 18^{th} century in Rajasthan by this community. A large group of them from 84 villages led by a lady called Amrita Devi laid down their lives in an effort to protect the trees from being felled on the orders of the *Maharaja* (King) of Jodhpur. After this incident, the *Maharaja* gave a strong royal decree preventing the cutting of trees in all Bishnoi villages.

In the 20th century, it began in the hills where the forests are the main source of livelihood, since agricultural activities cannot be carried out easily. The Chipko movement of 1973 was one of the most famous among these. The first Chipko action took place spontaneously in April 1973 in the village of Mandal in the upper Alakananda valley and over the next five years spread to many districts of the Himalayas in Uttar Pradesh. It was sparked off by the government's decision to allot a plot of forest area in the Alaknanda valley to a sports goods company. This angered the villagers because their similar demand to use wood for making agricultural tools had been earlier denied. With encouragement from a local NGO (non-governmental organization), DGSS (Dasoli Gram Swarajya Sangh), the women of the area, under the leadership of an activist, Chandi Prasad Bhatt, went into the forest and formed a circle around the trees preventing the men from cutting them down.

The success achieved by this protest led to similar protests in other parts of the country. From their origins as a spontaneous protest against logging abuses in Uttar Pradesh in the Himalayas, supporters of the Chipko movement, mainly village women, have successfully banned the felling of trees in a number of regions and influenced natural resource policy in India. Dhoom Singh Negi, Bachni Devi and many other village women, were the first to save trees by hugging them. They coined the slogan: 'What do the forests bear? Soil, water and pure air'. The success of the Chipko movement in the hills saved thousands of trees from being felled.

Some other persons have also been involved in this movement and have given it a proper direction. Mr Sunderlal Bahuguna, a Gandhian activist and philosopher, whose appeal to Mrs Indira Gandhi, the then Prime Minister of India, resulted in the green-felling ban. Mr Bahuguna coined the Chipko slogan: 'ecology is permanent economy'. Mr Chandi Prasad Bhatt, is another leader of the Chipko movement. He encouraged the development of local industries based on the conservation and sustainable use of forest wealth for local benefit. Mr Ghanasyam Raturi, the Chipko poet, whose songs echo throughout the Himalayas of Uttar Pradesh, wrote a poem describing the method of embracing the trees to save them from felling:

' Embrace the trees and
Save them from being felled;
The property of our hills,
Save them from being looted.'

The Chipko protests in Uttar Pradesh achieved a major victory in 1980 with a 15-year ban on green felling in the Himalayan forests of that state by the order of Mrs Indira Gandhi, the then Prime Minister of

India. Since then, the movement has spread to many states in the country. In addition to the 15-year ban in Uttar Pradesh, the movement has stopped felling in the Western Ghats and the Vindhyas and has generated pressure for a natural resource policy that is more sensitive to people's needs and ecological requirements.

1.5.2 Silent Valley

The Save Silent Valley was a social movement aimed at the protection of Silent valley, an evergreen tropical forest in the Palakkad district of Kerala, India. It was started in 1973 to save the Silent Valley Reserve Forest from being flooded by a hydroelectric project. The valley was declared as Silent Valley National Park in 1985. Nonetheless the controversy surrounding the valley is still on...

1.5.2.1 **Background**

The Kuntipuzha is a major river that flows 15 km southwest from Silent Valley. It takes its origin in the lush green forests of Silent Valley. In 1928 the location at Sairandhri on the Kunthipuzha River was identified as an ideal site for electricity generation. A study and survey was conducted in 1958 of the area about the possibility of a hydroelectric project of 120 MV and one costing Rs. 17 Crore was later proposed by the Kerala State Electricity Board.

1.5.2.2 **Beginnings**

After the announcement of imminent dam construction the valley became the focal point of "Save Silent Valley", India's fiercest ecological debate of the decade. Because of concern about the endangered lion-tailed macaque, the issue was brought to public attention. Romulus Whitaker, founder of the Madras Snake Park and the Madras Crocodile Bank, was probably the first person to draw public attention to the small and remote area. In 1977 the Kerala Forest Research Institute carried out an Ecological Impact study of the Silent Valley area and proposed that the area be declared a Biosphere Reserve.

In 1978 Smt. Indira Gandhi, the Honorable Prime Minister of India, approved the project, with the condition that the State Government enact Legislation ensuring the necessary safeguards. Also that year the IUCN (Ashkhabad, USSR, 1978) passed a resolution recommending protection of Lion-tailed Macaques in Silent Valley and Kalakkad and the controversy heated up. In 1979 the Government of Kerala passed Legislation regarding the Silent Valley Protection Area (Protection of Ecological stable Act of 1979) and issued a notification declaring the exclusion of the Hydroelectric Project Area from the proposed National Park.

1.5.2.3 **Participants**

Kerala Sasthra Sahithya Parishad (KSSP) effectively aroused public opinion on the requirement to save Silent Valley. They also published a Techno-economic and Socio-Political assessment report on the Silent Valley Hydroelectric project. The poet activist Sugathakumari played an important role in the silent valley protest and her poem "Marathinu Stuthi" (Ode to a Tree) became a symbol for the protest from the intellectual community and was the opening song/prayer of most of the "save the Silent Valley" campaign meetings. Dr. Salim Ali, an eminent ornithologist of the Bombay Natural History Society, visited the Valley and appealed for cancellation of the Hydroelectric Project. A petition for a writ was filed before the High Court of Kerala, against the clear cutting of forests in the Hydroelectric Project area and the court ordered a stop to the clear cutting.

Dr. M.S. Swaminathan, the renowned Agricultural Scientist, and then Secretary to the Department of Agriculture, called at the Silent Valley region and his suggestion was 389.52 km² including the Silent Valley (89.52 km²), New Amarambalam (80 km²), Attappadi (120 km²) in Kerala and Kunda in Tamil Nadu (100 km²) reserve forests, should be made into a National Rainforest Biosphere Reserve, with the aim of "*preventing erosion of valuable genes from the area*".

In January 1980 the Hon. High Court of Kerala lifted the ban on clear cutting, but then the Hon. Prime Minister of India requested the Government of Kerala to stop further works in the project area until all aspects were fully discussed. In December, the Government of Kerala declared the Silent Valley area, excluding the Hydroelectric Project area, as a National Park.

In 1982 a multidisciplinary committee with Prof. M. G. K. Menon as chairman, was created to decide if the Hydroelectric Project was feasible without any important ecological damage. Early in 1983, Prof. the Menon's Committee submitted its report. After a careful study of the Menon report, the Hon. Prime Minister of India decided to abandon the Project. On October 31, 1984 Indira Gandhi was assassinated and on November 15 the Silent Valley forests were declared as a National Park, though the boundaries of the Silent Valley Park were limited and no buffer zone was created, despite recommendations by expert committees and scientists.

1.5.2.4 Park inaugurated

Ten months later, on September 7, 1985 the Silent Valley National Park was formally inaugurated and a memorial at Sairandhri to Indira Gandhi was unveiled by Shri. Rajiv Gandhi, the new Hon. Prime Minister of India. On September 1, 1986 Silent Valley National Park was designated as the core area of the Nilgiri Biosphere Reserve.

Since then, a long-term conservation effort has been undertaken to preserve the Silent Valley ecosystem.

1.5.2.5 A New Dam proposal

In 2001 a new Hydro project was proposed and the "Man vs. Monkey debate" was revived. The proposed site of the dam (64.5 m high and 275 m long) is just 3.5 km downstream of the old dam site at Sairandhiri, 500 m outside the National Park boundary. The 84 km² catchment of the project area included 79 km² of the Silent Valley National Park.

The Kerala Minister for Electricity called The Pathrakkadavu dam (PHEP) an "eco-friendly alternative" to the old Silent Valley project. The PHEP was designed as a run-off-the-river project with an installed capacity of 70 MW in the first phase (105 MW eventually) and an energy generation of 214 million units (Mu) with a minimal gross storage of 0.872 million cubic meters. The claim was that the submergence area of the PHEP would be a negligible .041 km² compared to 8.30 km² submergence of the 1970s (SVHEP). However, The spectacular waterfall between the Neelikkal and Pathrakkadavu hills bordering the Silent Valley will disappear if the proposed Pathrakkadavu hydroelectric project is implemented. - Image

During January to May 2003 a rapid Environmental Impact Assessment (EIA) was carried out during by the Thiruvananthapuram-based Environmental Resources Research Centre and its report was released in December, stating that forest lost due to the project would be just .2216 km², not including the 7.4 km approach road and land to be acquired for the powerhouse in Karapadam.

1.5.3 Narmada Bachao Andolan

Narmada Bachao Andolan (NBA) is a social movement consisting of *adivasis*, farmers, environmentalists, and human rights activists against a number of large dams being built across the Narmada river. The river flows through the states of Gujarat, Maharashtra, and Madhya Pradesh in India. Sardar Sarovar Dam in Gujarat is one of the biggest dams on the river and was one of the first focal points of the movement.

Their mode of campaign includes hunger strikes and garnering support from film and art personalities (notably Bollywood actor Aamir Khan). Narmada Bachao Andolan, with its leading spokespersons Medha Patkar and Baba Amte, received the Right Livelihood Award in 1991.

1.5.3.1 History of the dam project

Post-1947, investigations were carried out to evaluate mechanisms for using water from the Narmada River, which flows into the Arabian Sea after passing through the states of Madhya Pradesh, Gujarat and Maharashtra. Due to inter-state differences in implementing schemes and sharing of water, the Narmada Water Disputes Tribunal was constituted by the Government of India on 6 October 1969 to adjudicate over the disputes. This tribunal investigated the matters referred to it and responded after more than 10 years. On 12 December 1979, the decision as given by the tribunal, with all the parties at dispute binding to it, was released by the Indian government.

As per the tribunal's decision, 30 major, 135 medium, and 3000 small dams, were granted approval for construction including raising the height of the Sardar Sarovar dam.

In 1985, after hearing about the Sardar Sarovar dam, Medha Patkar and her colleagues visited the project site and noticed that the project work being shelved due to an order by the Ministry of Environment and Forests, Government of India. The reasons for this was cited as "non-fulfillment of basic ecological conditions and the lack of completion of crucial studies and plans". What she noticed was that the people who were going to be affected were given no information but for the offer for rehabilitation. Due to this, the villagers had many questions about why their permission was not taken to whether a good assessment of the ensuing destruction was taken. Furthermore, the officials related to the project had no answers to their questions. While World Bank, the financing agency for this project, came into the picture, Patkar approached the Ministry of Environment to seek clarifications. She realized, after seeking answers from the ministry, that the project was not sanctioned at all and wondered as to how the funds were even sanctioned by the World Bank. After several studies, they realized that the officials had overlooked the post-project problems.

Through Patkar's channel of communication between the government and the residents, she provided critiques to the project authorities and the governments involved. At the same time, her group realized that all those displaced were only given compensation for the immediate standing crop and not for displacement and rehabilitation.

As Patkar remained immersed in the Narmada struggle, she chose to quit her Ph.D. studies and focus entirely on the Narmada activity. Thereafter, she organized a 36-day solidarity march among the neighboring states of the Narmada valley of Madhya Pradesh to the Sardar Sarovar dam site. She said that the march was "a path symbolizing the long path of struggle (both immediate and long-term) that [they] really had". The march was resisted by the police, who according to Patkar were "caning the marchers and arresting them and tearing the clothes off women activists".

1.5.3.2 Formation

There were groups such as Gujarat-based Arch-Vahini (Action Research in Community Health and Development) and Narmada Asargrastha Samiti (Committee for people affected by the Narmada dam), Madhya Pradesh-based Narmada Ghati Nav Nirman Samiti (Committee for a new life in the Narmada Valley) and Maharashtra-based Narmada Dharangrastha Samiti (Committee for Narmada dam-affected people) who either believed in the need for fair rehabilitation plans for the people or who vehemently opposed dam construction despite a resettlement policy.

While Medha Patkar established Narmada Bachao Andolan in 1989, all these groups joined this national coalition of ecological and human rights activists, scientists, academics and project-affected people with a non-violent approach.

1.5.3.3 Aftermath

Within the focus of Narmada Bachao Andolan towards the stoppage of the Sardar Sarovar dam, Patkar advised the addition of the World Bank to their propaganda. Using the right to fasting, she undertook a 22-day fast that almost took her life. In 1991, Patkar's actions led to an unprecedented independent review by the World Bank. The Morse Commission, appointed in June 1991 at the recommendation of World Bank President Barber Conable, conducted its first independent review of a World Bank project. This independent review stated that "performance under these projects has fallen short of what is called for under Bank policies and guidelines and the policies of the Government of India." This resulted in the Indian Government is pulling out of its loan agreement with the World Bank. In response, Patkar said "It is very clear and obvious that they used this as a face-saving device," suggesting that if this were not to happen, the World Bank eventually would have withdrawn the loan. The World Bank's participation in these projects was cancelled in 1995.

She undertook a similar fast in 1993 and resisted evacuated from the dam site. In 1994, the Bachao Andolan office was attacked repeatedly by a couple of political parties, where Patkar and other activists were physically assaulted and verbally abused. In protest, a few NBA activists and she began a fast; 20 days later, they were arrested and forcibly fed intravenously.

1.5.3.4 Supreme Court's decision

The Supreme Court's decision is still pending, seeking stoppage of construction of the Sardar Sarovar dam. The court initially ruled the decision in the Andolan's favor, thereby effecting an immediate stoppage of work at the dam and directing the concerned states to first complete the rehabilitation and replacement procedure.

The Court deliberated on this issue further for several years but finally upheld the Tribunal Award and allowed the construction to proceed, subject to conditions. The court introduced a mechanism to monitor the progress of resettlement pari passu with the raising of the height of the dam through the Grievance Redressal Authorities (GRA) in each of the party states. The court’s decision referred in this document, given in the year 2000 after seven years of deliberations, has paved the way for completing the project to attain full envisaged benefits. The court's final line of the order states, "Every endeavor shall be made to see that the project is completed as expeditiously as possible".

Subsequent to the court’s verdict, Press Information Bureau (PIB) featured an article which states that:

The Narmada Bachao Andolan has rendered a yeoman's service to the country by creating a high-level of awareness about the ecological and rehabilitation and relief aspects of Sardar Sarovar and other projects on the Narmada. But, after the court verdict it is incumbent on it to adopt a new role. Instead of 'damning the dam' any longer, it could assume the role of vigilant observer to see that the resettlement work is as humane and painless as possible and that the ecological aspects are taken due care of."

1.5.3.5 People involved

Amongst the major celebrities who have shown their support for the Narmada Bachao Andolan are Booker Prize winner Arundhati Roy and Aamir Khan.

1994 saw the launch of *Narmada: A Valley Rises*, by filmmaker Ali Kazimi. It documents the five-week Sangharsh Yatra of 1991. The film went on to win several awards and is considered by many to be a classic on the issue. In 1996, veteran documentary filmmaker, Anand Patwardhan, made an award-winning documentary: *A Narmada Diary*.

1.5.3.6 Criticism

The Narmada dam's benefits include the provision of drinking water, power generation and irrigation facilities. However, the campaign led by the NBA activists has held up the project's completion, and the NBA supporters have attacked by local people who accepted compensation for moving. Others have argued that the Narmada Dam protesters are little more than ecological extremists who use pseudosystematic agitprop to scuttle the development of the region and that the dam will provide agricultural benefits to millions of poor in India. There had also been instances when the NBA activists turned violent and attacked a rehabilitation officer from the Narmada Valley Development Authority (NVDA) and caused damage to the contractor's machinery.

The NBA has been accused of lying under oath in court about land ownership in areas affected by the dam. The Supreme Court has mulled perjury charges against the group.

Review Questions

1. Define the Environmental Geography?
2. Explain the Ecology & Ecosystem?
3. Explain the Environmental Disaster?
4. Explain the Environmental Hazards?

Discussion Questions

Discuss the Environmental Movement?

Chapter 2- Environmental Hazards

Learning Objectives

- To define the Environmental Hazards Management.
- To explain the Risk Analysis.
- To explain the Pre- Hazard Conditions.
- To describe the Post Hazard Condition.

2.1 Concept of Management of Environmental Hazards

Environmental management is a procedure that industries, companies, and individuals undertake to regulate and protect the health of the natural world. In most cases, it does not actually involve managing the environment itself, but rather is the procedure of taking steps and promoting behaviors that will have a positive impact on how ecological resources are used and protected. Organizations engage in ecological management for a couple of different reasons, but caring for the natural world, following local laws and rules about conservation, and saving money are usually near the top of most lists. Management plans look different in different industries, but all aim for roughly the same goals.

2.1.1 Plan, Do, Check

Most management plans roughly follow a “plan, do, check” model. The first step, planning, requires the organization to set out specific goals, like reducing wastewater, implementing new standards for toxin disposal, or better managing erosion. Once an endpoint has been identified, leaders need to come up with a systematic way of bringing the entire organization into compliance.

Next, the company needs to actually take steps to implement the procedures laid out in the planning stage. This is the “do” aspect, and it can be harder than it sounds. Action typically requires a coordinated effort that must be put into place over several weeks or months; more often than not, this step is ongoing, and cannot easily be “checked off” a list.

Progress assessments are one of the best ways for organizations to gauge how well they are sticking to their plan. Regular status checks help groups see what is working and what is not, ideally with time to spare to make changes and improvements as needed. This step often involves reports and analysis collected over time, and feedback that is generated during this phase is frequently used to improve planning and doing going forward. In most cases, ecological management is something of a cyclical procedure that continues — and continues adapting — as time goes by.

2.1.2 Training Requirements

In most companies and industries, this work is something that requires at least a bit of training. A commitment to something like conservation or better methods of waste disposal is a good starting place, but actually being effective in achieving end results usually requires expertise and a lot of coordination. If everyone in the organization is not on board and using the same methods, it can be hard to succeed. When a management plan is properly enforced and executed by people with the right know-how, however, companies often see the benefits both to their core business and to the environment.

2.1.3 Commitment Costs

Getting the right training and laying the proper groundwork during the planning phase is often one of the costliest parts of the procedure. Most companies do not have the expertise to train their employees, which means that this must be outsourced. A number of different consulting companies offer educational services and tutorials, often on a case-by-case or project-by-project basis. Organizations that are really serious about long-term management initiatives sometimes also choose to create new positions and hire ecological experts in a more permanent capacity.

There are also usually a number of technical costs. Special equipment may be needed to measure outputs or intakes, For example, and software programs and special computer metrics are often required to make sense of results and readings over time. It may also be the case that managing ecological consequences require more expensive ways of doing business. Many companies are used to doing things the least expensive way possible, which is something that must often be reconsidered when how those methods affect the environment are taken into account.

2.1.4 Economic and Other Benefits

In a great many cases, the benefits of an ecological management plan far outweigh the initial expenses. These include the prevention of pollution, the conservation of natural resources like water, and increased energy efficiency. Over time, these benefits often add up to important cost *savings* in bills and utility outputs. Well-executed plans can also help companies avoid costly fines in places where there is regulation of energy consumption, disposal, and other ecological concerns.

Though a lot depends on the dynamics of the individual organization, following a management plan can also be a way to build employee relationships and foster company support around a single goal. Groups that are able to mobilize their workforce around an issue that people believe in often see better productivity and morale in areas totally unrelated to the core issue. This means that a company committing to better safety standards for something like oil transportation might incidentally realize better office productivity, which in turn can lead to higher sales.

2.1.5 Identification of Hazards

2.1.5.1 Types of hazards

A hazard is anything that has the potential to cause harm or injury to a person or damage to plant or property. Hazards can result from:

- The work environment
- The use of machinery and substances
- Poor work design
- Inappropriate systems and procedures.

Common types of workplace hazards can be categorized as follows:

- Physical (noise, lighting, temperature)
- Chemical (poisonous, dusts, vapors, fumes, hazardous substances)

- Biology (viruses, plants, parasites, blood, other body fluids)
- Mechanical (slips, trips and falls, manual handling, plant and equipment)
- Electrical (shock, ignition, plant and equipment)
- Psychological (stress, repetitive work, shift work, violence/aggression).

Other hazards that are more specific to the event environment may include:

- Temporary structures (construction, stability, crowd capacity, collapse)
- Dangerous or flammable materials (projectiles, fireworks, vehicles, exhaust fumes, open fires, gas cylinders)
- Movement of heavy equipment (uneven sites, vicinity of other personnel, scheduling)
- Spectators (public access, egress, behavior)
- Climate (rain, hail, wind, heat, thunderstorms).

2.1.5.2 **Hazard identification methods**

Using a range of hazard identification methods and strategies increases your ability to accurately identify all potential hazards within an event environment or other workplace.

The hazard identification step of the risk management procedure must be carried out in a timely manner which may be on a predetermined basis such as monthly, quarterly or annually. For events, hazard identification must occur at all phases of an event including venue handover, bump-in, and bump-out as well as during the event.

These methods provide a benchmark by which hazards are able to be identified and are used in conjunction with observing the work environment and work activities undertaken in that environment. These types of benchmark strategies and tools are located within standards, codes of practice and guidelines relevant to your industry, workplace and work activities.

Identification strategy	When and how used	Tools
Workplace inspection	Routine basis: daily, weekly, monthly, quarterly. Visual checking and discussion with work colleagues by the manager and an employee	Checklist outlining all areas to be inspected within the workplace/site (sample below)

Job safety analysis	General observation of work practices during the course of the work or pre-arranged and conducted by Area Supervisors and work colleagues Each stage of the work practice is recorded and hazards and control measures identified within each stage. This ensures that the job is carried out in the safest manner possible.	Job analysis work statement to record the major steps in a job procedure, corresponding hazards within each step and control measures for each step. (sample below)
Plant and equipment safety check	These are pre-operational checks conducted by the person using the plant or equipment.	Checklist, eg amusement equipment checklist, vehicle checklists, electrical equipment checklists
Manual handling checks	Completed by the Area Manager/Supervisor and employees on tasks that contain manual handling. These checks are conducted on a scheduled basis; at least once per year is recommended.	Checklist to itemise manual handling movements
Review of workplace injury and illness	This is conducted by the Area Manager and the members of the organisations OHS consultation committee/representatives or management in general.	Accident reports, sick leave forms and Injury/illness register to record all details of injuries and illnesses that occur in the workplace
Investigation of incidents/accidents	An investigation is conducted by the area supervisor and another work colleague after an incident has occurred.	Accident reports, investigation documents to record all information pertaining to the incident/accident
Complaints/notification of hazards from employee, volunteers etc	These can occur at any time during work activities and anyone can make a complaint or notification.	Hazard report form to record the details of identified hazards
Feedback through consultation mechanisms	This occurs when work colleagues meet to discuss OHS issues.	Minutes of meetings

2.1.5.3 Specialist hazard identification

The following hazard identification strategies are generally carried out by specialists.

Identification strategy	When and how used	Tools

Ergonomic assessment	An ergonomic assessment refers to an assessment undertaken at an individual's workstation to ensure that the workstation is set up to meet the individual's physical requirements so as to avoid injuries such as neck and back strain, eye strain, fatigue etc. The assessment is usually carried out initially at the employment of a worker and on an annual basis to ensure that safe working conditions are maintained.	Checklist to itemise appropriate ergonomic working conditions
Site safety audit	An audit conducted on a specific area or activity or on a company's OHS management system. This could include: OHS responsibilities, risk management procedure, work proceduree s, tools and equipment safety requirements, OHS training, OHS reporting and recording. While this can be conducted by management it is usually conducted by external OHS auditors on an annual or bi-annual basis at the request of an organisations executive management.	Audit documentation outlining all areas of the organisations OHS management system
Environmental monitoring	Environmental monitoring is usually carried out by specialists in their selected environmental field. The fields may include hazardous substances, confined spaces, soil contamination, asbestos, noise and pest control.	Environmental reports

2.1.5.4 Recording hazards

Once hazards have been identified they must be recorded and workplaces have a hazard register that allows all relevant information to be recorded.

It is helpful to distinguish the hazard from the associated safety risk and the possible outcome that may result if the hazard is left unchecked. Defining the three separately will assist in the next phase of the procedure (i.e. risk assessment).

Event hazards may be considered as follows.

Hazard	Safety risk	Possible outcomes

(description of hazard and location)	(consequences from the hazard)	(if the hazard is not controlled)
Contractors working at height to install rigging and equipment	Falling Climbing equipment failure	Death Permanent injury
Use of fork lift with other personnel in the event area	Person being hit by vehicle	Death Permanent injury
Exhaust fumes from exhibition display, eg cars	Exhaust build up Crowd crush	Exhaust inhalation Death or injury
Boxes left in main doorway	Trip hazard	Medical attention required
Wet floor from spilled liquid	Slips and falls Burns if liquid is corrosive	First aid

2.2 Hazards Zonation & Risk Analysis

2.2.1 Hazards Zonation

A seismic zone is a region in which the rate of seismic activity remains fairly consistent. This may mean that seismic activity is incredibly rare, or that it is extremely common. Some people often use the term “seismic zone” to talk about an area with an increased risk of seismic activity, while others prefer to talk about “seismic hazard zones” when discussing areas where seismic activity is more frequent.

Many nations have government agencies concerned with seismic activity. These agencies use the data they collect about seismic activity to divide the nation into various seismic zones. A number of different zoning systems are used, from numerical zones to colored zones, with each number or color representing a different level of seismic activity. In the United States, for example, the seismic zones are divided between one and five, with zone five being the most at risk of seismic activity.

Most high-activity seismic zones are located along what is known as fault zones, regions of the Earth's crust which are prone to seismic activity. Fault zones often occur where continental plates meet, but they can also be found around volcanoes. A major fault zone in North America far from any plate boundaries is caused by a huge bubble of magma under the Earth's crust which periodically bubbles up into an explosive volcanic eruption.

By breaking a country up into different seismic zones, a nation can identify areas which are at increased risk. These areas may have more stringent building codes which are designed to make them safer in the event of a tremor , and emergency services in a high risk seismic zone may be required to have special tremor training and frequent drills to practice responding to a tremor . Insurance companies usually also increase their rates in a high-activity seismic zone.

One of the biggest hazards beyond the basic shaking of a tremor for people in a high-activity seismic zone is liquefaction. Soil liquefaction occurs when loose sediments become suspended in water as a result of seismic activity which pushes the water table upward. When soil liquefaction occurs, the ground is no longer able to support the weight of buildings, highways, and other structures, causing collapses to occur. Underground utility lines may be severed during the procedure, resulting in potentially explosive leaks of gas along with widespread contamination with sewage. In high-activity zones which are also subject to liquefaction, a tremor can be extremely dangerous.

2.2.2 Risk Analysis

Risk can be defined as the likelihood or probability of a given hazard of a given level causing a particular level of loss of damage (Alexander, Confronting catastrophe, 2000). David Alexander outlined the elements of risk (Alexander, Confronting catastrophe, 2000) as populations, communities, the built environment, the natural environment, economic activities and services which are under threat of calamity in a given area. Risk can be equated with a simple equation, although it is not mathematical. The total risk according to UNDRO 1982 is the "sum of predictable deaths, injuries, destruction, damage, disrupt, and costs of repair and mitigation caused by a calamity of a particular level in a given area or areas. Mathematically it can be written as

Total risk = (Sum of the elements at risk) x (hazard x vulnerability)

David Alexander distinguishes between risk and vulnerability saying that 'vulnerability refers to the potential for casualty, destruction, damage, disruption or other form of loss in a particular element: risk combines this with the probable level of loss to be expected from a predictable magnitude of hazard (which can be considered as the manifestation of the agent that produces the loss).' (Wisner, et al., 1994). As hazard has varying degrees of severity (Wisner, et al., 1994) the more intense or severe the hazard, the greater vulnerability there will be a potential for damage and destruction is increased with respect to severity of the hazard. Ben Wisner argues that risk or calamity is 'a compound function of the natural hazard and the number of people, characterized by their varying degrees of vulnerability to that specific hazard, who occupy the space and time of exposure to the hazard event.' (Wisner, et al., 1994). This is simplified into an equation:

R = H x V

Risk, vulnerability and hazard are the three factors or elements which we are considering here in this pseudo equation. Another definition of risk given by Factor analysis of information risk which may be related to calamity is 'the probable frequency and probable magnitude of future losses. Again this definition focuses on the probability of future loss whereby the degree of vulnerability to hazard represents the level of risk on a particular population, built environment or environment. The relationship between severity of ecological hazard, probability and risk. Hazard severity will obviously vary it is necessary to outline threats posed by hazard. These are: 1. Hazards to people – death, injury, disease and stress 2. Hazards to goods – property damage and economic loss 3. Hazards to environment –loss of flora and fauna, pollution and loss of amenity (Smith, 1992)

2.2.2.1 Prioritization of hazards

2.2.2.1.1 SMUG model – a basis for prioritizing hazards

In an emergency or disaster management the SMUG model of identifying and prioritizing risks associated with natural and technological hazards is an effective tool. SMUG stands for Seriousness, Manageability, Urgency and Growth and are the criteria used for prioritization. The SMUG model provides an effective means of prioritizing hazards based upon the aforementioned criteria in order to address the risks posed by the hazards to the avail of effecting effective readiness, reduction, response and recovery.

Seriousness can be defined as "The relative impact in terms of people and dollars. This includes the potential for lives to be lost and potential for injury as well as the physical, social and as mentioned, economic losses that may be incurred.

Manageability can be defined as "the relative ability to mitigate or reduce the hazard (through managing the hazard, or the community or both)". Hazards presenting a high risk and as such requiring important amounts of risk reduction initiatives will be rated higher.

Urgency is related to the probability of risk of hazard and is defined in terms of how imperative it is to address the hazard.

Growth is the potential for the hazard or event to expand or increase in either probability or risk to the community or both. Should vulnerability increase, potential for growth may also increase.

An example of the numerical ratings for each of the four criteria is shown below:

Manageability	High = 7+	Medium = 5–7	Low = 0–4
Urgency	High = 20yr>	Medium = 20yr<	Low = 100yrs
Growth	High = 3	Medium = 2	Low = 1
Seriousness	High = 4-5	Medium = 2-3	Low = 0-1

2.3 Hazard Awareness

2.3.1 Hazard Perception

Hazard perception is a complex human cognitive skill which allows a person to identify a potentially hazardous situation. Well-developed hazard perception skills allow persons engaged in activities such as driving to identify hazards in time to take appropriate preventative action. Instinctively slowing down when approaching a group of children playing on the roadside is a good practical example of this skill. Unfortunately, these skills depend on the individual's visual and auditory perception abilities and are largely honed by experience, which leads to increased risks during learning curves. They are also highly individualistic characteristics and are not equally developed in all persons.

A person's ability to assess a situation as it unfolds and quickly identify potential dangers in time to avoid them is known as hazard perception. This skill is a product of auditory and visual perception abilities, situational and life experience, and complex cognitive procedures such as attention to detail and concentration. The accumulation of experience both in terms of situational exposure in a specific activity and general life experience is hard-gained over extended periods and, unfortunately, goes hand-in-hand with elevated risks in the early stages of any learning curve. Both areas of perceptive ability and combined experience play a critical role in hazard perception as demonstrated by the previously-mentioned driving example.

When approaching the playing children, the driver assimilates both visual and auditory information, the extent of which depended on the individual's ability in these areas of perception coupled with his or her level of concentration at the time. Unfortunately, if the driver does not see or hear the children in time to react proactively, any hazard avoidance actions will be crammed into the split second that it takes one of the children to chase a ball into the road. This type of situation all-too-often leads to tragic loss of life and forcefully stresses the importance of identifying any type of impaired perception early.

When the potential hazard posed by the children's activities has been visually identified, situational experience should alert the driver to the fact that it will be difficult to avoid a collision at higher speeds, so he or she slows down when approaching. In addition, life experience may have taught the driver to make allowances for the fact that the children will, while engrossed in their games, be unlikely to pay sufficient attention to traffic to avoid causing a potential hazard. These visual inputs and the two pieces of gaining knowledge combined with vigilance and attention to detail should see the driver slow down and possibly move away from the curb while passing the children. A driver who does not pick up on the hazard flags and knocks one of the children down is not necessarily a bad driver, technically, but does exhibit a dangerous deficiency of hazard identification skills.

These skills are highly individualistic and are not equally developed in all individuals. Fortunately, it is possible, in many cases, to identify the lack of hazard recognition abilities, allowing the individual to concentrate on improving them. Training programs for many hazardous activities include comprehensive hazard perception tests which will give early warning of any deficiencies in the person's inherent skills. These tests are included in many driver's education programs, machine operator's training, and the training programs for law enforcement and security personnel. Luckily, for many people, stable vigilance in hazardous environments can, to a point, offset a lack in hazard perception.

2.3.2 Risk Perception

Risk perception refers to how a person perceives the risk associated with a specific activity or event. Just about every activity, from grocery shopping to skydiving, has some type of risk associated with it. Most people weigh the potential for danger against the benefits of the activity and decide whether to go through with it. Risk perception is highly subjective, with each person making their own decision about the potential danger involved in various activities.

Large, life-altering decisions rely heavily on risk perception. For example, a couple deciding to try to have another baby after a miscarriage often weighs the risk of losing that baby against the potential benefits of another pregnancy. If the couple decides that the chances of a happy ending are higher than the risk of losing the baby, they may determine that it is safe to proceed with their plans.

People also make minor decisions based on risk perception every day. These small decisions include deciding the best moment to merge into traffic or choosing a lunch based on foods that haven’t caused the diner to suffer from indigestion in the past. Most people make their decisions without giving it much thought, or base those decisions on routines that have worked well for them in the past. For example, a diner choosing her lunch may get the same thing every day, or have a limited selection from which she chooses. She already knows that none of those selections are likely to disagree with her, so she perceives their risk to her gastrointestinal tract as minor.

In some cases, a person's risk perception can be skewed by life events, making him or her believe that something is far riskier than statistics indicate it is. For example, statistically speaking, most planes make it to their destination without crashing. Those who have lost a loved one in a plane crash, however, overestimate the risk involved in flying and may develop a phobia about using that mode of transportation.

Psychological disorders can also play a role in altering risk perception. Someone with anxiety disorder may overestimate the risk associated with everyday tasks, such as driving to work or giving an important presentation in front of a group of colleagues. Other disorders can cause affected individuals to underestimate the risk of an activity. Drugs and alcohol can also importantly impact the user's ability to properly assess risk. Alcohol, for example, tends to lower inhibitions and allows drinkers to believe they are less susceptible to harm.

2.4 **Pre- Hazard Conditions: Warning & Precautions.**

India has over the years developed, upgraded and modernized the monitoring, forecasting and warning systems to deal with cyclones, floods, droughts and tremors.

2.4.1 **Cyclone**

The India Meteorological Department (IMD) is responsible for cyclone tracking and warning to the concerned user agencies. Cyclone tracking is done through INSAT Satellite and 10 cyclone detection radars. A warning is issued to cover ports, fisheries, and aviation departments. The warning system provides for a cyclone alert of 48 hours, and a cyclone warning of 24 hours. There is a special Disaster Warning System (DWS) for dissemination of cyclone warning through INSAT Satellite to designated addresses at isolated places in local languages.

The extent of headway made in cyclone warning is evidenced by two situations of 1977 and 1990 in Andhra Pradesh coast which was hit by cyclones accompanied by high storm surges of almost the same intensities. The number of deaths in 1977 was over 10,000 whereas the loss of human lives in 1990 were less than 1000. Timely warnings issued by the IMD enabled the administration in evacuating and transporting over half a million people from the affected areas.

2.4.2 Floods

The Central Water Commission (CWC) has a flood forecasting system covering 62 major rivers in 13 States with 157 stations for transmission of flood warnings on a real time basis. In 1995, 8,566 forecasts were issued with a percentage accuracy of 95 per cent. There are 55 hydro-meteorological stations also in the 62 river basins.

VHF/HF wireless communication system is used for data collection with micro- computers at the forecasting centers. Hydrological models are increasingly used for inflow and flood forecasting and the forecasts are communicated to the administrative and the engineering departments for dissemination.

2.4.3 **Droughts**

The IMD has divided the entire country into 35 meteorological sub-divisions. It issues weekly bulletins on rainfall indicating normal, excess and deficient levels and also the percentages of departure from the normal.

The CWC monitors the levels of 60 major reservoirs with weekly reports of reservoir levels and corresponding capacity for the previous year and the average of the previous 10 years. Similar monitoring of smaller reservoirs by the Irrigation Departments of State Governments give advance warnings of hydrological droughts with below average stream flows, cessation of stream flows and decrease in soil moisture and groundwater levels.

Based on the input from IMD and CWC on the rainfall behavior and the water levels in the reservoirs respectively and the information on crop situations received from the local sources, the National Crop Climate Watch Group monitors the drought conditions. Remote sensing techniques are also used for monitoring drought conditions based on vegetative and moisture index status.

2.4.4 **Earthquake**

On the basis of past tremors of magnitude 5 and above and intensities ranging from V to IX superimposed on the magnitude information and also drawing upon tectonic features in the near past, Tremor Zonation maps have been prepared. IMD operates a network of 36 seismic monitoring stations. After the Maharashtra tremor of September 1993, a plan to upgrade and modernize the National network of seismological operations equipped with the State-of-art technology instruments is now in progress.

2.4.5 **Preparing For Natural Hazards: Some Precautions**

Lightning, flooding, hailstorms and fires – just a few of the natural calamities that we are beginning to see an increase in all over the world. Extremely dangerous and not easy to predict with high degrees of certainty, these acts of nature have claimed many lives and resulted in so much devastation. Many of us aren't calamity management specialists, so here are some precautions you can take should any of these natural hazards are prevalent in your area.

2.4.5.1 Lightning:

It is important to note that there are four different types of lightning, namely cloud-to-sky lightning, intra-cloud lightning, inter-cloud lightning and cloud-to-ground lightning – the latter being the most dangerous. If lightning strikes, it is advised that those indoors should stand clear of windows, mirrors, doors and electrical appliances. If lightning warnings are sent out, it is important to unplug any appliances before the storm even begins, but never during. If outdoors, the best thing to do is to get into a hard topped car. If this is not possible, avoid standing near tall objects, including trees. Standing in a group of people is not advisable, so spread out over the area to avoid attracting lightning. Finally, get as far away from any body of water as possible, as being near either one when lightning strikes could prove to be fatal.

2.4.5.2 Floods:

One of the most treacherous aftereffects of heavy storms is the flooding associated with it. The rainfall leaves behind pools of water that open up numerous opportunities for various hosts of diseases to breed.

Cholera and Typhoid are amongst the most common diseases easily spread as a result of flooding, as the water becomes stagnant, thus allowing the bacteria to build up. If flood warnings arise, it is important to determine which areas are potential flood zones, and stay away from them. If evacuation is advised, do so immediately. Try and get to a safe area as soon as possible, before it becomes cut off by flood waters.

2.4.5.2 Fires:
Once a fire starts, it can become very difficult to get it under control. It is best to take preventative measures to ensure that the possibility of fires is very limited, instead of having to later control a very dangerous situation. Firstly, make sure that any dead vegetation in the garden or surrounding areas has been cleared away. Dry leaves, weeds and plants serve as fuel for fires, and should one break loose, it will only make the fire stronger. Furthermore, making sure that hosepipes, tapes and any other irrigation systems are in working will be of great help should a fire break out; accessible water could really help limit the damage caused. Finally, disposing of cigarettes properly could save numerous lives, both animal and human. Make sure that cigarettes are completely put out before throwing them away.

2.4.5.3 Hail storms:
Hail storms have the potential to turn dangerous very suddenly. Varying in size, hail can be very hazardous and cause enormous damage to crops, livestock and buildings. In the event of such a storm, a brick structure is most likely to be the safest space to seek shelter. If at all possible, moving to another level of the house, one not directly underneath the roof is advised. Before the storm arrives, make sure that cars are parked away (preferably also a brick structure) so as to minimize the damage done to them.
1. The people should be sure that all breakables are stored safely, foodstuffs and water are prepared and big items need is on the floor.
2. Green vegetations like trees surrounding houses should be pruned regularly or even cut down if they are in state for damaging property if disturbed, for example wind .

3. Trustful information regarding natural calamities is always published on the news. Professionals who relay information to the media always closely monitors volcanic eruptions and hurricanes . Instructions and advice are also given on the emergency news as to how to prepare safe during occurrence of natural calamities.

4. In the event that the gas or electricity becomes hazardous, everybody should also familiarize themselves with turning off the gas and electricity supply to their houses .

5. The originals or copies of valuable certificates like birth certificates, marriage certificates, passports, citizenship, etc. should not be left behind in an elected house but always carried on the person in the event that there is no return.

6. Learn how to shut off gas, water and electricity in case the lines are damaged.

7. If power is lost, turn off major appliances and keep refrigerators and freezers closed.

8. Check your home for cracks and damage, including the roof, chimneys and foundation.

2.5 Post Hazard Condition: Rescue, Assessment & Rehabilitation

India, besides evolving effective post-disaster management operations, has also formulated and implemented pre-disaster mitigation programs and sectoral development programs to reduce the impact of calamities as well as reduce the socioeconomic vulnerabilities. The reconstruction programs in the aftermath of calamities such as cyclones and tremors are also aimed at building calamity resistant structures to withstand the impact of natural hazards in the future.

2.5.1 Floods

Structural methods of flood mitigation have attracted an investment of about Rs. 4,000 crore between 1957 and 1995 in construction of new embankments (16200 kms), drainage channel (32000 Km) and raising 4700 critical villages above the flood level. These measures have protected an estimated area of 14.4 million hectares.

Multipurpose dams and reservoirs have been built with flood moderation as one of the objectives. Examples of flood moderation through multi-purpose dams are the Damodar Valley systems in eastern India, Hirakud dam in Orissa and the Bhakra on river Sutlej. The Damodar valley system has a flood absorption capacity of 1,867, mcm. which moderates probable floods of 28,300 cusses to 7,075 cusses in the valley.

Control of the premature situation of multi-purpose reservoirs and checking degradation of catchment areas is attempted through a scheme of soil conservation, River Valley Project (RVP) in the catchments of major rivers. The scheme covers 581 watersheds in 27 catchments spread over 17 States.

The increasing trend in the flood damage observed in India during the seventies led to attempts for the development of flood plains in a regulated manner. A model Bill on flood plain Zoning was circulated to the State Governments as early as 1975 to enact suitable legislation for restricting the encroachment of the flood plains and for their development in a regulated manner. The model Bill emphasises on non-structural measures. The main features of the model bill were:

(a) Designating flood zoning authority;

(b) Delineation of flood plain;

(c) Notification of limits of flood plains;

(d) Restrictions on use of floodplains;

(e) Compensation; and

(f) Power to remove construction after prohibition.

During the decades of the 1960s to 1980s there has been dependent on structural measures. As structural measures alone have not yielded the desired results and flood damages continue to show increasing trend, non-structural measures such as flood forecasting, flood plain zoning, flood proofing of the civic amenities of the affected villages, changing the cropping pattern and public participation in flood management works are being given a fair trial. These measures are also cost and time effective.

2.5.2 Drought

India has given attention to irrigation development by harnessing water through the medium reservoirs, developing traditional systems of tanks and exploiting groundwater. The average annual investment on major and medium term irrigation projects rose from 75.00 Crores in the First Five Year Plan to Rs. 2500.00 Crores in the Eighth Five Year Plan creating a total potential of 38.0 million hectares.

The irrigation potential has not been fully utilized for want of on-farm development works like field channels, land levelling, field drains and absence of an appropriate system of water distribution to ensure appropriate water management. The Government of India is now operating a Command Area Development Program (CADP) to strengthen the water management capabilities and enhance the effectiveness of irrigation water application.

The Desert Development Program (DDP) started in 1977-78 aims at controlling the procedure of desertification and mitigating the adverse effects of drought in the desert areas through such projects as afforestation, sand-dune stabilization, shelter belt plantation, grassland development and soil and moisture conservation. A similar program directed at drought prone areas is under implementation since 1973 and is titled Drought Prone Areas Program (DPAP). The DPAP is under implementation in 149 districts in 14 States and the DDP in 36 districts in 7 States.

Seventy per cent of India's cultivated land is in the rain-fed areas, which often suffer reverses in agricultural production and face drought conditions. A program titled National Watershed Development Project for Rain-fed Areas (NWDPRA) has been devised and is under implementation. This program adopts development measures for all the spatial components of watersheds i.e. arable land, non-arable land and drainage lines as one organic geo-hydrological entity. The objective is to achieve conservation of rain water, control of soil erosion, regeneration of green cover and promotion of dryland farming systems including horticulture, agro-forestry, pasture development and livestock management as well as household production systems.

There are large areas of degraded land of over 100 million hectares in the country which could be reclaimed. Most of the land needs only basic water and soil conservation measures and some amount of plantation and protection work. By protecting, regenerating and restoring the degraded land the pressure on the remaining land, forests and pastures can be reduced. A National Wasteland Development Board has been constituted for promoting integrated wasteland development. The National Forest Conservation Act (1980) is an attempt to bring down the erosion of forest cover all over the country.

Natural calamity, particularly droughts throws up huge unemployment and under-employment problems in the rural areas. Providing wage employment to the rural poor has been an integral part of rural development efforts. The Jawahar Rozgar Yojana (JRY) envisaged for this purpose is the largest such program in the country. The objectives of the program is to generate additional gainful employment for the unemployed and under-employed men and women in rural areas. The Employment Assurance Schemes (EAS) are implemented to provide employment opportunities mostly in drought prone areas.

2.5.3 Cyclone

Measures such as building of cyclone shelters, afforestation in coastal areas, etc. have been undertaken to deal with cyclones. Reconstruction projects have been taken up in areas affected by major calamities by building elements for mitigation of possible future calamities. The Cyclone Reconstruction Project implemented in the coastal Andhra Pradesh during 1990-93 consisted of such components as housing and public infrastructure, drainage and rural water supply. It also included such mitigation efforts as expanding road and communication network, planning of shelter belt plantation and building up of cyclone shelters.

2.5.4 Earthquake

Since much loss of life during the past tremors in the world has occurred due to the collapse of non-engineered traditional buildings of clay, stones and bricks, and since the bulk of the housing in India consists of such buildings, studies on this problem were started at the University of Roorkee in 1960. Very useful recommendations regarding upgrading of such buildings were available in the G.S.I. Memories on the 1934 Bihar Tremor and 1935 Quetta (now in Pakistan) Tremor . These efforts resulted in the preparation and publication of IS:4326 in 1976. After the Koyna Tremor , the research efforts were devoted to shake-table tests on larger scale specimens for checking the validity of the reinforcing recommendations of IS:4326 and also to further refine the analysis procedures. The Monograph published by the International Association of Tremor Engineering, namely, Basic Theorys of Seismic Codes, Part II, Non-Engineered Construction, 1980 included many results of the Indian experience, particularly in regard to masonry and wooden buildings. This Monograph has been revised and updated as "Guidelines for Tremor Resistant Non-Engineered Construction", October, 1986.

The Department of Science and Technology (DST) is executing a World Bank assisted project on Seismological Instrumentation Upgradation and other Collateral Geophysical studies in the Indian Peninsular region. Major organizations like India Meteorological Department, National Geophysical Research Institute, Survey of India, Geological Survey of India and some academic institutions are participating in the World Bank project. Under the project, it is planned to (i) upgrade 20 existing seismological observatories of IMD, (ii) set up 3 Telemetered Seismic Clusters (iii) 10 new Digital Seismic Observatories in the shield region and (iv) Strong Motion Instruments both for free field and structural response studies (v) Geodetic studies using GPS technology.

2.5.5 Long Term Mitigation/Reduction Measures

To improve calamity management strategy and to enhance our capabilities to mitigate the impact of calamities in the country in the long-run, the following areas have been identified for implementation:-

i) Intensive training for building up human resource development to improve awareness and capabilities for successful calamity management.

ii) The documentation of events of various natural calamities so as to highlight the lessons learnt in tackling future disasters.

iii) Long-term mitigation measures which will focus on various programs keeping in view the goals and objectives of IDNDR.

iv) For achieving long-term results there is a need to examine critically the development programs in relation to disaster management in different areas and suggest priorities and strategies for inclusion in the ongoing plans.

v) To create awareness among the general public about the various aspects of the calamities and benefits of the countermeasures.

vi) Programs of undertaking consultancy services, research programs etc. to increase the level of understanding and evolving appropriate measures to improve the quality of the disaster management.

vii) To have an integrated approach in developing professional disaster management strategy.

viii) Improvement of forecasting, warning and communication system for effective disaster management.

A Central Sector Scheme on Natural Disaster Management Programs (NDMP) is being implemented for the first time since December 1993. The main objective of the program is to enhance the national capability for calamity reduction, preparedness and mitigation. The program is also expected to enhance the level of awareness of the community about calamities they are likely to face and prepare them adequately to face the crisis situation.

The components of the program are:-

i) Human resource development,

ii) Activities under IDNDR,

iii) Research and consultancy services,

iv) Documentation of major events,

v) Strengthening of NDM Division,

vi) Establishment of National Centre for Disaster Management (NCDM) at the Centre and the Natural Disaster Management Faculties in States.

The major achievements of the program so far are :-

i) Setting up of the National Centre for Disaster Management in the Indian Institute of Public Administration , New Delhi, in 1995.

ii) Setting up of separate Disaster Management Faculties in Training Institutes in 16 out of 25 States in the country,

iii) Documentation of major events like Uttarkashi and Latur tremors, research studies on landslides in Kerala and Sikkim, droughts in Rajasthan and cyclone mitigation in Andhra Pradesh.

iv) Preparation of Sourcebook for use of trainees of the Lal Bahadur Shastri National Academy of Administration,

v) Organizing/Sponsoring of about training programs/seminars on various aspects of natural disaster management,

vi) Public education and community awareness campaign through Newspapers, postal stationery, observation of World Disaster Reduction Day and films,

vii) Reprinting of 45000 copies of IDNDR publication for children in English and Hindi for distribution among school children.

2.5.6 VISION 2020

In spite of initiating various disaster mitigation measures, the trend of losses is not indicating any sign of improvement. Population pressure, ecological degradation , migration and unplanned urbanization are some of the major factors contributing to increase vulnerability. As such need has been felt to accelerate the pace of disaster mitigation efforts in the country. It is planned to give more stress in the following areas :-

- Linkage of calamity mitigation with development plans,
- Effective communication system ,
- Use of latest information technology,
- Insurance,
- Extensive public awareness and education campaigns particularly in the rural areas
- Legal and legislative support,
- Involvement of private sector ,

- Strengthening of institutional mechanism including Natural Disaster Management Division in the nodal Ministry of Agriculture,

International co-operation at regional and bi-lateral level

2.5.7 Regional co-operation - in 21st Century

Most of the world worst calamity tends to occur between the Tropic of Cancer and Tropic of Capricorn. Coincidentally, this cover most of the Asian countries and some of them are poorer countries of the world. The calamities cause enormous destruction and human suffering in the developing countries . Environmental degradation, which is often a result of economic development associated human settlement pattern that ignore appropriate resource management to increase the vulnerability of these countries to natural hazards and exacerbate their impact. The losses due to the natural calamities reduce the pace of sustained economic development and often lead to a heavy drain on available resources diverting them from pursuing development aims.

Each country rich or poor should try to develop and maintain an effective disaster management capability appropriate to their needs. The management system must be seen as logical and desirable in the cost benefit terms and fit within the existing socio- economic system. It also underlines the necessity for co-ordinated international action in order to strengthen all aspects of disaster management wherever possible.

Regional cooperation for effective disaster management system is needed broadly in the following areas :-

- Hazard and vulnerability analysis
- Human resource development
- Exchange of information through internet
- Disaster management network at the regional level
- Networking of the regional institutes

2.5.8 India and regional co-operation

India is facing various types of disasters on account of its larger size and geographical location. The country has over the years well tested calamity relief and rehabilitation mechanism. Relief manuals and codes backed by a contingency action plan along with the allocation of resources, facilitates the emergency management operations. A Plan scheme has been initiated with the objective of enhancing the national capability for calamity reduction and preparedness. The institutional mechanism has been strengthened by establishing the calamity management centers at the national and state levels.

The National Centre for Disaster Management , New Delhi is working in the area of natural disaster management for human resource development, creation of database, documentation of calamitous events, research studies and networking of the institutions at the national and international level. In addition small Centres on disaster management are also operating in the state level training institutes. A large number of institutes already engaged in the activities related to disaster reduction activities. Some of these are:-

- Department of Tremor Engineering, University of Roorkee,
- Building Material Technology Promotion Council, New Delhi.
- Central Building Research Institute, Roorkee.
- National Civil Defense College, Nagpur.
- National Institute of Rural Development, Hyderabad.
- Indian Institutes of Technology, Delhi, Kanpur, Mumbai.

- Structural Engineering Research Centres, Hyderabad.
- Central Road Research Institute, New Delhi.
- Council for Systematic and Industrial Research, New Delhi.
- Anna University, Channai.
- Indra Gandhi National Open University, New Delhi.

India can provide the available expertise for calamity relief and rehabilitation, human resource development , preparation of relief manuals and codes , contingency action plans , post calamity evaluation and information technology.

Review Questions

1. Define the Environmental Hazards Management?
2. Explain the Risk Analysis?
3. Explain the Pre- Hazard Conditions?
4. Explain the Post Hazard Condition?

Discussion Questions

Discuss the Environmental Hazards and mitigation options?

Chapter 3- Hazards & Disaster

Learning Objectives

- To define the Atmospheric Hazards.
- To explain the Cyclone, Drought, Floods.
- To explain the Green House effect.
- To describe the Sustainable Development.

3.1 Atmospheric Hazards & Disaster: Causes, Effects & Management

Atmospheric hazards include things such as oxygen deficiencies, dusts, chemical vapors, welding fumes, fogs, and mists that can interfere with the body's ability to transport and utilize oxygen, or that have negative toxicological effects on the human body.

Before entry into most confined spaces, a multi-gas meter is commonly used to determine levels of oxygen, carbon monoxide, hydrogen sulfide, and the concentration of combustible gas. Other types of meters and sensors are available to detect concentration of specific gases (chlorine, sulfur dioxide, etc.) if needed.

The most common atmospheric hazards associated with confined spaces are:

- Oxygen Deficiency
- Oxygen Displacement
- Flammable Atmospheres
- Toxic Gases

3.1.1 Oxygen Deficiency

Low levels of oxygen can be caused by the consumption of oxygen during open flame operations such as welding, cutting, or brazing. In addition, low levels of oxygen can be present in manholes that are located near garbage dumps, landfills and swampy area where fermentation has caused the consumption of oxygen.

3.1.2 Oxygen Displacement:

Some types of gases will "push" or displace oxygen from a confined space. An example of this is nitrogen. Nitrogen is commonly used to purge some types of tanks. If a person were to enter into the space before the nitrogen was properly removed and vented from the tank, death could result in a matter of minutes.

3.1.3 Flammable Atmospheres

Three components are necessary for an atmosphere to become flammable: fuel, oxygen, and a source of ignition.

Some confined spaces may contain solvents, fuel oil, gasoline, kerosene, etc. which provide the fuel for combustion. In order for an atmosphere to become flammable, it must have the proper mixture of fuel and oxygen. If the concentration of a specific gas is below the lower explosive limit (LEL) it is too lean to burn. If the concentration is above the upper explosive limit (UEL) it is too rich to burn.

3.1.4 Toxic gases:

Toxic gases can be present in a confined space because the type of manufacturing procedure uses toxic substances as part of the production procedure, or biological and chemical "breakdown" of the product being stored in a tank, and from maintenance activities (welding) being performed in the confined space.

3.1.5 Common types of toxic gases encountered in confined spaces are:

- *Hydrogen Sulfide* - "sewer gas" a colorless gas with the odor of rotten eggs. Excessive exposure has been linked to many confined space deaths. Hydrogen sulfide causes a loss of our sense of smell, causing people to mistakenly think that the gas has left the space. Hydrogen sulfide inhibits the exchange of oxygen on the cellular level and causes asphyxiation.
- *Carbon monoxide* - is an odorless, colorless gas that is formed by burning carbon based fuels (gas, wood). Carbon monoxide inhibits the bodies ability to transport oxygen to all parts of the body.
- *Solvents* - many solvents, such as kerosene, gasoline, paint strippers, Degreasers, etc. are not only flammable, but if inhaled at high concentrations can cause central nervous system (CNS) effects. CNS effect can include dizziness, drowsiness, lack of concentration, confusion, headaches, coma and death.

3.1.6 Physical Hazards

We've talked about one of the two classifications of confined space hazards, atmospheric hazards. The other major type of hazard found in confined spaces is physical hazards.

Physical hazards can be considered as hazards that cause the body to become physically stressed. Unlike atmospheric hazards, physical hazards can be detected through your senses of (touch, sight).

Some examples of physical hazards are:

- Engulfment: Engulfment and suffocation in a loose material that is stored in a hopper or grain silo is another hazard that can be encountered in a confined space. A condition called bridging can occur in tanks and silos. Bridging occurs when grain, coal, sawdust, etc. clings to the side of a vessel that is being emptied. The bridging material becomes unstable and may collapse at any time, engulfing workers standing on or below the material.
- Other hazards: Other hazards that must be considered are: moving and rotating equipment, electrical energy, hot or cold conditions, wet or slick surfaces, and excessive noise.

Now that you have a background on the types of hazards that can be found in confined spaces, let's learn how to determine if a certain work area would be considered a confined space.

3.1.7 Emergency and Rescue Procedures

Confined space accidents are rare, but when accidents happen in a confined space they are usually fatal. Two major factors that lead to fatal injuries in confined spaces are:

1) Failure to recognize and control the hazards associated with confined spaces.

2) Inadequate or incorrect emergency response. When the emergency response is usually a spontaneous reaction to an emergency situation, this can lead to multiple fatalities.

3.2 Cyclone, Drought, Floods.

3.2.1 Cyclone

In meteorology, a **cyclone** is an area of closed, circular fluid motion rotating in the same direction as the Earth. This is usually characterized by inward spiraling winds that rotate anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere of the Earth. Most large-scale cyclonic circulations are centered on areas of low atmospheric pressure. The larger low-pressure systems are cold-core polar cyclones and extratropical cyclones which lie on the synoptic scale. According to the NHC glossary, warm-core cyclones such as tropical cyclones and subtropical cyclones also lie within the synoptic scale. Mesocyclones, tornadoes and dust devils lie within the smaller mesoscale. Upper level cyclones can exist without the presence of a surface low, and can pinch off from the base of the Tropical Upper Tropospheric Trough during the summer months in the Northern Hemisphere. Cyclones have also been seen on extraterrestrial planets, such as Mars and Neptune. Cyclogenesis describes the procedure of cyclone formation and intensification. Extratropical cyclones form as waves in large regions of enhanced mid-latitude temperature contrasts called baroclinic zones. These zones contract to form climate fronts as the cyclonic circulation closes and intensifies. Later in their life cycle, cyclones occlude as cold core systems. A cyclone's track is guided over the course of its 2 to 6 day life cycle by the steering flow of the cancer or subtropical jet stream.

Climate fronts separate two masses of air of different densities and are associated with the most prominent meteorological phenomena. Air masses separated by a front may differ in temperature or humidity. Strong cold fronts typically feature narrow bands of thunderstorms and severe climate, and may on occasion be preceded by squall lines or dry lines. They form west of the circulation center and generally move from west to east. Warm fronts from east of the cyclone center and are usually preceded by stratiform precipitation and fog. They move poleward ahead of the cyclone path. Occluded fronts form late in the cyclone life cycle near the center of the cyclone and often wrap around the storm center.

Tropical cyclogenesis describes the procedure of development of tropical cyclones. Tropical cyclones form due to latent heat driven by important thunderstorm activity, and are warm core. Cyclones can transition between extratropical, subtropical, and tropical phases under the right conditions. Mesocyclones form as warm core cyclones over land, and can lead to tornado formation. Waterspouts can also form from mesocyclones, but more often develop from environments of high instability and low vertical wind shear. In the Atlantic basin, a tropical cyclone is generally referred to as a hurricane (from the name of the ancient Central American deity of the wind, Huracan), a cyclone in the Indian Ocean and parts of the Pacific, and a typhoon in the Northwest Pacific region.

3.2.1.1 Structure

There are a number of structural characteristics common to all cyclones. A cyclone is a low pressure area. A cyclone's center (often known in a mature tropical cyclone as the eye), is the area of lowest atmospheric pressure in the region. Near the center, the pressure gradient force (from the pressure in the center of the cyclone compared to the pressure outside the cyclone) and the force from the Coriolis effect must be in an approximate stable, or the cyclone would collapse on itself as a result of the difference in pressure.

Because of the Coriolis effect, the wind flow around a large cyclone is counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Cyclonic circulation is sometimes referred to as contra solem. In the Northern Hemisphere, the fastest winds relative to the surface of the Earth therefore occur on the eastern side of a northward-moving cyclone and on the northern side of a westward-moving one; the opposite occurs in the Southern Hemisphere. (The wind flow around an anticyclone, on the other hand, is clockwise in the northern hemisphere, and counterclockwise in the southern hemisphere.)

3.2.1.2 Formation

Cyclogenesis is the development or strengthening of a cyclonic circulation in the atmosphere (a low pressure area). Cyclogenesis is an umbrella term for several different procedures, all of which result in the development of some sort of cyclone. It can occur at various scales, from the microscale to the synoptic scale.

Extratropical cyclones form as waves along climate fronts before occluding later in their life cycle as cold core cyclones.

Tropical cyclones form due to latent heat driven by important thunderstorm activity, and are warm core.

Mesocyclones form as warm core cyclones over land, and can lead to tornado formation. Waterspouts can also form from mesocyclones, but more often develop from environments of high instability and low vertical wind shear. Cyclogenesis is the opposite of cyclolysis, and has an anticyclone (high pressure system) equivalent which deals with the formation of high pressure areas—Anticyclogenesis.

The surface low has a variety of ways of forming. Topography can force a surface low when dense low-level high pressure system ridges in east of a north-south mountain barrier. Mesoscale convective systems can spawn surface lows which are initially warm core. The disturbance can grow into a wavelike formation along the front and lower will be positioned at the crest. Around the low, flow will become cyclonic, by definition. This rotational flow will push polar air equatorward west of the low via its trailing cold front, and warmer air with push poleward low via the warm front. Usually the cold front will move at a quicker pace than the warm front and “catch up” with it due to the slow erosion of higher density airmass located out ahead of the cyclone and the higher density airmass sweeping in behind the cyclone, usually resulting in a narrowing warm sector. At this point an occluded front forms where the warm air mass is pushed upwards into a trough of warm air aloft, which is also known as a trowel.

Tropical cyclogenesis is the technical term describing the development and strengthening of a tropical cyclone in the atmosphere. The mechanisms through which tropical cyclogenesis occurs are distinctly different from those through which mid-latitude cyclogenesis occurs. Tropical cyclogenesis involves the development of a warm-core cyclone, due to important convection in a favorable atmospheric environment. There are six main requirements for tropical cyclogenesis: sufficiently warm sea surface temperatures, atmospheric instability, high humidity in the lower to middle levels of the troposphere, enough Coriolis force to develop a low pressure center, a preexisting low level focus or disturbance, and low vertical wind shear. An average of 86 tropical cyclones of tropical storm intensity form annually worldwide, with 47 reaching hurricane/typhoon strength, and 20 becoming intense tropical cyclones (at least Category 3 intensity on the Saffir–Simpson Hurricane Scale).

3.2.1.2 Synoptic scale

The following types of cyclones are identifiable in synoptic charts.

3.2.1.2.1 Surface-based types

There are three main types surface-based cyclones: Extratropical cyclones, Subtropical cyclones and Tropical cyclones

3.2.1.2.2 Extratropical cyclone

An **extra tropical cyclone** is a synoptic scale low pressure climate system that does not have tropical characteristics, being connected with fronts and horizontal gradients in temperature and dew point otherwise known as "baroclinic zones".

The descriptor "extratropical" refers to the fact that this type of cyclone generally occurs outside of the tropics, in the middle latitudes of the planet. These systems may also be described as "mid-latitude cyclones" due to their area of formation, or "post-tropical cyclones" where extratropical transition has occurred, and are often described as "depressions" or "lows" by climate forecasters and the general public. These are the everyday phenomena which along with anti-cyclones, drive the climate over much of the Earth.

Although extratropical cyclones are almost always classified as baroclinic since they form along zones of temperature and dewpoint gradient within the westerlies, they can sometimes become barotropic late in their life cycle when the temperature distribution around the cyclone becomes fairly uniform with radius. An extratropical cyclone can transform into a subtropical storm, and from there into a tropical cyclone, if it dwells over warm waters and develops central convection, which warms its core. One intense type of extratropical cyclone that strikes during wintertime is a *Nor'easter*.

3.2.1.2.3 Polar low

A **polar low** is a small-scale, short-lived atmospheric low pressure system (depression) that is found over the ocean areas poleward of the main polar front in both the Northern and Southern Hemispheres. Polar lows are cold-core so they can be considered as a subset of extratropical cyclones. Polar lows were first identified on the meteorological satellite imagery that became available in the 1960s, which revealed many small-scale cloud vortices at high latitudes. The most active polar lows are found over certain ice-free maritime areas in or near the Arctic during the winter, such as the Norwegian Sea, Barents Sea, Labrador Sea and Gulf of Alaska. Polar lows dissipate rapidly when they make landfall. Antarctic systems tend to be weaker than their northern counterparts since the air-sea temperature differences around the continent are generally smaller. However, vigorous polar lows can be found over the Southern Ocean. During winter, when cold-core lows with temperatures in the mid-levels of the troposphere reach −45 °C (−49 °F) move over open waters, deep convection forms which allows polar low development to become possible. The systems usually have a horizontal length scale of less than 1,000 kilometers (620 mi) and exist for no more than a couple of days. They are part of the larger class of mesoscale climate systems. Polar lows can be difficult to detect using conventional climate reports and are a hazard to high-latitude operations, such as shipping and gas and oil platforms. Polar lows have been referred to by many other terms, such as polar mesoscale vortex, Arctic hurricane, Arctic low, and cold air depression. Today the term is usually reserved for the more vigorous systems that have near-surface winds of at least 17 m/s.

3.2.1.2.4 Subtropical

A **subtropical cyclone** is a climate system that has some characteristics of a tropical cyclone and some characteristics of an extratropical cyclone. They can form between the equator and the 50th parallel. As early as the 1950s, meteorologists were unclear whether they should be characterized as tropical cyclones or extratropical cyclones, and used terms such as quasi-tropical and semi-tropical to describe the cyclone hybrids. By 1972, the National Hurricane Center officially recognized this cyclone category. Subtropical cyclones began to receive names off the official tropical cyclone list in the Atlantic Basin in 2002. They have broad wind patterns with maximum sustained winds located farther from the center than typical tropical cyclones, and exist in areas of weak to moderate temperature gradient.

Since they form from initially extratropical cyclones which have colder temperatures aloft than normally found in the tropics, the sea surface temperatures required for their formation are lower than the tropical cyclone threshold by three degrees Celsius, or five degrees Fahrenheit, lying around 23 degrees Celsius. This means that subtropical cyclones are more likely to form outside the traditional bounds of the hurricane season. Although subtropical storms rarely have hurricane-force winds, they may become tropical in nature as their cores warm.

3.2.1.2.5 Tropical

A **tropical cyclone** is a storm system characterized by a low pressure center and numerous thunderstorms that produce strong winds and flooding rain. A tropical cyclone feeds on heat released when moist air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms such as nor'easters, European windstorms, and polar lows, leading to their classification as "warm core" storm systems. The term "tropical" refers to both the geographic origin of these systems, which form almost exclusively in tropical regions of the globe, and their formation in Maritime Tropical air masses. The term "cyclone" refers to such storms' cyclonic nature, with counterclockwise rotation in the Northern Hemisphere and clockwise rotation in the Southern Hemisphere. Depending on their location and strength, tropical cyclones are referred to by other names, such as hurricane, typhoon, tropical storm, cyclonic storm, tropical depression, or simply as a cyclone.

While tropical cyclones can produce extremely powerful winds and torrential rain, they are also able to produce high waves and damaging storm surge. They develop over large bodies of warm water, and lose their strength if they move over land. This is the reason coastal regions can receive important damage from a tropical cyclone, while inland regions are relatively safe from receiving strong winds. Heavy rains, however, can produce important flooding inland, and storm surges can produce extensive coastal flooding up to 40 kilometers (25 mi) from the coastline. Although their effects on human populations can be devastating, tropical cyclones can also relieve drought conditions. They also carry heat and energy away from the tropics and transport it toward temperate latitudes, which makes them an important part of the global atmospheric circulation mechanism. As a result, tropical cyclones help to maintain equilibrium in the Earth's troposphere.

Many tropical cyclones develop when the atmospheric conditions around a weak disturbance in the atmosphere are favorable. Others form when other types of cyclones acquire tropical characteristics. Tropical systems are then moved by steering winds in the troposphere; if the conditions remain favorable, the tropical disturbance intensifies, and can even develop an eye. On the other end of the spectrum, if the conditions around the system deteriorate or the tropical cyclone makes landfall, the system weakens and eventually dissipates. A tropical cyclone can become extratropical as it moves toward higher latitudes if its energy source changes from heat released by condensation to differences in temperature between air masses; From an operational standpoint, a tropical cyclone is usually not considered to become subtropical during its extratropical transition.

3.2.1.3 Upper level types

3.2.1.3.1 Polar cyclone

A **polar cyclone** is a vast area of low pressure which strengthens in the winter and weakens in the summer. A polar cyclone is a low pressure climate system, usually spanning 1,000 kilometers (620 mi) to 2,000 kilometers (1,200 mi), in which the air circulates in a counterclockwise direction in the northern hemisphere, and a clockwise direction in the southern hemisphere. In the Northern Hemisphere, the polar cyclone has two centers on average. One center lies near Baffin Island and the other over northeast Siberia. In the southern hemisphere, it tends to be located near the edge of the Ross ice shelf near 160 west longitude. When the polar vortex is strong, westerly flow descends to the Earth's surface. When the polar cyclone is weak, important cold outbreaks occur.

3.2.1.3.1.1 TUTT cell

Under specific circumstances, upper cold lows can break off from the base of the Tropical Upper Tropospheric Trough (TUTT), which is located mid-ocean in the Northern Hemisphere during the summer months. These upper tropospheric cyclonic vortices, also known as TUTT cells or TUTT lows, usually move slowly from east-northeast to west-southwest, and generally do not extend below 20,000 feet in altitude. A weak inverted surface trough within the trade wind is generally found underneath them, and they may also be associated with broad areas of high-level clouds. Downward development results in an increase of cumulus clouds and the appearance of a surface vortex. In rare cases, they become warm-core, resulting in the vortex becoming a tropical cyclone. Upper cyclones and upper troughs which trail tropical cyclones can cause additional outflow channels and aid in their intensification procedure. Developing tropical disturbances can help create or deepen upper troughs or upper lows in their wake due to the outflow jet emanating from the developing tropical disturbance/cyclone.

3.2.1.4 Mesoscale

The following types of cyclones are not identifiable in synoptic charts.

3.2.1.4.1 Mesocyclone

A **mesocyclone** is a vortex of air, 2.0 kilometers (1.2 mi) to 10 kilometers (6.2 mi) in diameter (the mesoscale of meteorology), within a convective storm. Air rises and rotates around a vertical axis, usually in the same direction as low pressure systems in both northern and southern hemispheres. They are most often cyclonic, that is, associated with a localized low-pressure region within a supercell. Such storms can feature strong surface winds and severe hail. Mesocyclones often occur together with updrafts in supercells, where tornadoes may form. About 1700 mesocyclones form annually across the United States, but only half produce tornadoes.

3.2.1.4.2 Tornado

A tornado is a violently rotating column of air that is in contact with both the surface of the earth and a cumulonimbus cloud or, in rare cases, the base of a cumulus cloud. They are often referred to as twisters or cyclones, although the word cyclone is used in meteorology, in a wider sense, to name any closed low pressure circulation.

3.2.1.4.2 Dust Devil

A dust devil is a strong, well-formed, and relatively long-lived whirlwind, ranging from small (half a meter wide and a few meters tall) to large (more than 10 meters wide and more than 1000 meters tall). The primary vertical motion is upward. Dust devils are usually harmless, but can on rare occasions grow large enough to pose a threat to both people and property.

3.2.1.4.3 Waterspout

A columnar vortex forming over water connected to a cumuliform cloud. Similar to a tornado but usually weaker.

3.2.1.4.4 Steam devil

A gentle vortex over calm water or wetland made visible by rising water vapor.

3.2.2 Drought

Drought is an extended period when a region notes a deficiency in its water supply, whether surface or underground water. A drought can last for months or years, or may be declared after as few as 15 days. Generally, this occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause important damage and harm to the local economy.

Many plant species, such as cacti, have adaptations such as reduced leaf area and waxy cuticles to enhance their ability to tolerate drought. Some others survive dry periods as buried seeds. Semipermanent drought produces arid biomes such as deserts and grasslands. Most arid ecosystems have inherently low productivity.

This global phenomenon has a widespread impact on agriculture. Lengthy periods of drought have long been a key trigger for mass migration and played a key role in a number of ongoing migrations and other humanitarian crises in the Horn of Africa and the Sahel.

According to F. Bagouls and Henri Gaussen's definition, a month is dry when the mean monthly precipitation in millimeters is equal to or lower than twice the mean monthly temperature in °C.

3.2.2.1 Consequences

Periods of droughts can have important ecological, agricultural, health, economic and social consequences. The effect varies according to vulnerability. For example, subsistence farmers are more likely to migrate during drought because they do not have alternative food sources. Areas with populations that depend on as a major food source are more vulnerable to famine.

Drought can also reduce water quality, because lower water flows reduce dilution of pollutants and increase contamination of remaining water sources. Common consequences of drought include:

- Diminished crop growth or yield productions and carrying capacity for livestock
- Dust bowls, themselves a sign of erosion, which further erode the landscape
- Dust storms, when drought hits an area suffering from desertification and erosion
- Famine due to lack of water for irrigation
- Habitat damage, affecting both terrestrial and aquatic wildlife
- Hunger, drought provides too little water to support food crops.
- Malnutrition, dehydration and related diseases
- Mass migration, resulting in internal displacement and international refugees
- Reduced electricity production due to reduced water flow through hydroelectric dams
- Shortages of water for industrial users
- Snake migration and increases in snakebites
- Social unrest
- War over natural resources, including water and food
- Wildfires, such as Australian bushfires, are more common during times of drought.

3.2.2.2 **Globally**

Drought is a normal, recurring feature of the climate in most parts of the world. It is among the earliest documented climatic events, present in the Epic of Gilgamesh and tied to the biblical story of Joseph's arrival in and the later Exodus from Ancient Egypt. Hunter-gatherer migrations in 9,500 BC Chile have been linked to the phenomenon, as has the exodus of early humans out of Africa and into the rest of the world around 135,000 years ago.

Modern people can effectively mitigate much of the impact of drought through irrigation and crop rotation. Failure to develop adequate drought mitigation strategies carries a grave human cost in the modern era, exacerbated by ever-increasing population densities.

Regions affected

Recurring droughts leading to desertification in the Horn of Africa have created grave ecological catastrophes, prompting massive food shortages, still recurring. To the north-west of the Horn, the Darfur conflict in neighboring Sudan, also affecting Chad, was fueled by decades of drought; combination of drought, desertification and overpopulation are among the causes of the Darfur conflict, because the Arab Baggara nomads searching for water have to take their livestock further south, to land mainly occupied by non-Arab farming peoples.

Approximately 2.4 billion people live in the drainage basin of the Himalayan rivers. India, China, Pakistan, Bangladesh, Nepal and Myanmar could experience floods followed by droughts in coming decades. Drought in India affecting the Ganges is of particular concern, as it provides drinking water and agricultural irrigation for more than 500 million people. The west coast of North America, which gets much of its water from glaciers in mountain ranges such as the Rocky Mountains and Sierra Nevada, also would be affected.

In 2005, parts of the Amazon basin experienced the worst drought in 100 years. A 23 July 2006 article reported Woods Hole Research Center results showing that the forest in its present form could survive only three years of drought. Scientists at the Brazilian National Institute of Amazonian Research argue in the article that this drought response, coupled with the effects of deforestation on regional climate, is pushing the rainforest towards a "tipping point" where it would irreversibly start to die. It concludes that the rainforest is on the brink of being turned into savanna or desert, with catastrophic consequences for the world's climate. According to the WWF, the combination of climate change and deforestation increases the drying effect of dead trees that fuels forest fires.

By far the largest part of Australia is desert or semi-arid lands commonly known as the outback. A 2005 study by Australian and American researchers investigated the desertification of the interior, and suggested that one explanation was related to human settlers who arrived about 50,000 years ago. Regular burning by these settlers could have prevented monsoons from reaching interior Australia. In June 2008 it became known that an expert panel had warned of long term, maybe irreversible, severe ecological damage for the whole Murray-Darling basin if it does not receive sufficient water by October. Australia could experience more severe droughts and they could become more frequent in the future, a government-commissioned report said on July 6, 2008. Australian environmentalist Tim Flannery, predicted that unless it made drastic changes, Perth in Western Australia could become the world's first ghost metropolis, an abandoned city with no more water to sustain its population.

East Africa currently faces its worst drought in decades, with crops and livestock destroyed. The U.N. World Food Program recently said that nearly four million Kenyans urgently needed food.

3.2.2.3 Causes

Generally, rainfall is related to the amount and dew point [determined by air temperature] of water vapor carried by regional atmosphere, combined with the upward forcing of the air mass containing that water vapor. If these combined factors do not support precipitation volumes sufficient to reach the surface, the result is a drought. This can be triggered by high levels of reflected sunlight, [high albedo], and above the average prevalence of high pressure systems, winds carrying continental, rather than oceanic air masses (i.e. reduced water content), and ridges of high pressure areas from behaviors which prevent or restrict the developing of thunderstorm activity or rainfall over one certain region. Oceanic and atmospheric climate cycles such as the El Niño-Southern Oscillation (ENSO) make drought a regular recurring feature of the Americas along the Midwest and Australia. *Guns, Germs, and Steel* author Jared Diamond see the stark impact of the multi-year ENSO cycles on Australian climate patterns as a key reason that Australian aborigines remained a hunter-gatherer society rather than adopting agriculture. Another climate oscillation known as the North Atlantic Oscillation has been tied to droughts in northeast Spain.

Human activity can directly trigger exacerbating factors such as over farming, excessive irrigation, deforestation, and erosion adversely impact the ability of the land to capture and hold water. While these tend to be relatively isolated in their scope, activities resulting in global climate change are expected to trigger droughts with a substantial impact on agriculture throughout the world, and especially in developing nations. Overall, global warming will result in increased world rainfall. Along with drought in some areas, flooding and erosion will increase in others. Paradoxically, some proposed solutions to global warming that focus on more active techniques, solar radiation management through the use of a space sunshade for one, may also carry with them increased chances of drought.

3.2.2.4 Types

As a drought persists, the conditions surrounding it gradually worsen and its impact on the local population gradually increases. People tend to define droughts in three main ways:

1. Meteorological drought is brought about when there is a prolonged period with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.
2. Agricultural droughts are droughts that affect crop production or the ecology of the range. This condition can also arise independently from any change in precipitation levels when soil conditions and erosion triggered by poorly planned agricultural endeavors cause a shortfall in water available to the crops. However, in a traditional drought, it is caused by an extended period of below average precipitation.
3. Hydrological drought is brought about when the water reserves available in sources such as aquifers, lakes and reservoirs fall below the statistical average. Hydrological drought tends to show up more slowly because it involves storing water that is used but not replenished. Like an agricultural drought, this can be triggered by more than just a loss of rainfall. For example, Kazakhstan was recently awarded a large amount of money by the World Bank to restore water that had been diverted to other nations from the Aral Sea under Soviet rule. Similar circumstances also place their largest lake, Balkhash, at risk of completely drying out.

3.2.2.5 **Protection and relief**

Strategies for drought protection, mitigation or relief include:

- Dams - many dams and their associated reservoirs supply additional water in times of drought.
- Cloud seeding - a form of intentional climate modification to induce rainfall.
- Desalination - of sea water for irrigation or consumption.
- Drought monitoring - Continuous observation of rainfall levels and comparisons with current usage levels can help prevent man-made drought. For example, analysis of water usage in Yemen has revealed that their water table (underground water level) puts at grave risk by over-use to fertilize their Khat crop. Careful monitoring of moisture levels can also help predict increased risk for wildfires, using such metrics as the Keetch-Byram Drought Index or Palmer Drought Index.
- Land use - Carefully planned crop rotation can help to minimize erosion and allow farmers to plant less water-dependent crops in drier years.
- Outdoor water-use restriction - Regulating the use of sprinklers, hoses or buckets on outdoor plants, filling pools, and other water-intensive home maintenance tasks.
- Rainwater harvesting - Collection and storage of rainwater from roofs or other suitable catchments.
- Recycled water - Former wastewater (sewage) that has been treated and purified for reuse.
- Transvasement - Building canals or redirecting rivers as massive attempts at irrigation in drought-prone areas.

3.2●3 Flood

A **flood** is an overflow of water that submerges land which is usually dry. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water. In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may occur as an overflow of water from water bodies, such as a river or lake, in which the water overtops or break levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an areal flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered important unless they flood the property or drown domestic animals.

Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry.

Some floods develop slowly, while others such as flash floods, can develop in just a few minutes and without visible signs of rain. Additionally, floods can be local, impacting a neighborhood or community, or very large, affecting entire river basins.

3.2.3.1 Principal types and causes

3.2.3.1.1 Areal (rainfall related)

Floods can happen on flat or low-lying areas when the ground is saturated and water either cannot run off or cannot run off quickly enough to stop accumulating. This may be followed by a river flood as water moves away from the flood plain into local rivers and streams.

Floods can also occur if water falls on an impermeable surface, such as concrete, paving or frozen ground, and cannot rapidly dissipate into the ground.

Localized heavy rain from a series of storms moving over the same area can cause a real flash flooding when the rate of rainfall exceeds the drainage capacity of the area. When this occurs in tilled fields, it can result in a muddy flood where sediments are picked up by runoff and carried as suspended matter or bed load.

3.2.3.1.2 Riverine

River flows may rise to flood levels at different rates, from a few minutes to several weeks, depending on the type of river and the source of the increased flow.

Slow rising floods most commonly occur in large rivers with large catchment areas. The increase in flow may be the result of sustained rainfall, rapid snow melt, monsoons, or tropical cyclones. Localized flooding may be caused or exacerbated by drainage obstructions such as landslides, ice, or debris.

Rapid flooding events, including flash floods, more often occur on smaller rivers, rivers with steep valleys or rivers that flow for much of their length over impermeable terrain. The cause may be localized convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier.

Dam-building beavers can flood low-lying urban and rural areas, occasionally causing some damage.

3.2.3.1.3 Estuarine and coastal

Flooding in estuaries is commonly caused by a combination of sea tidal surges caused by winds and low barometric pressure, and they may be exacerbated by high upstream river flow.

Coastal areas may be flooded by storm events at sea, resulting in waves over-topping defenses or in severe cases by a tsunami or tropical cyclones. A storm surge, from either a tropical cyclone or an extratropical cyclone, falls within this category.

3.2.3.1.4 Urban flooding

Urban flooding is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall overwhelming the capacity of drainage systems, such as storm sewers. Although sometimes triggered by events such as flash flooding or snowmelt, urban flooding is a condition, characterized by its repetitive and systemic impacts on communities, that can happen regardless of whether or not affected communities are located within formally designated floodplains or near any body of water. There are several ways in which stormwater enters properties: backup through sewer pipes, toilets and sinks into buildings; seepage through building walls and floors; the accumulation of water on the property and in public rights-of-way; and the overflow from water bodies such as rivers and lakes.

3.2.3.1.5 Catastrophic

Catastrophic flooding is usually associated with major infrastructure failures such as the collapse of a dam, but they may also be caused by damage sustained in a tremor or volcanic eruption.

3.2.3.2 Effects

3.2.3.2.1 Primary effects

The primary effects of flooding include loss of life, damage to buildings and other structures, including bridges, sewerage systems, roadways, and canals.

Floods also frequently damage power transmission and sometimes power generation, which then has knock-on effects caused by the loss of power. This includes loss of drinking water treatment and water supply, which may result in loss of drinking water or severe water contamination. It may also cause the loss of sewage disposal facilities. Lack of clean water combined with human sewage in the flood waters raises the risk of waterborne diseases, which can include typhoid, giardia, cryptosporidium, cholera and many other diseases depending upon the location of the flood.

Damage to roads and transport infrastructure may make it difficult to mobilize aid to those affected or to provide emergency health treatment.

Flood waters typically inundate farmland, making the land unworkable and preventing crops from being planted or harvested, which can lead to shortages of food both for humans and farm animals. Entire harvests for a country can be lost in extreme flood circumstances. Some tree species may not survive prolonged flooding of their root systems

3.2.3.2.2 Secondary and long-term effects

Economic hardship due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases is a common aftereffect of severe flooding. The impact on those affected may cause psychological damage to those affected, in particular where deaths, serious injuries and loss of property occur.

Urban flooding can lead to chronically wet houses, which are linked to an increase in respiratory problems and other illnesses. Urban flooding also has important economic implications for affected neighborhoods. In the United States, industry experts estimate that wet basements can lower property values by 10-25 percent and are cited among the top reasons for not purchasing a home. According to the U.S. Federal Emergency Management Agency (FEMA), almost 40 percent of small businesses never reopen their doors following a flooding calamity.

3.2•3.3 Flood forecasting

Anticipating floods before they occur allows for precautions to be taken and people to be warned so that they can be prepared in advance for flooding conditions. For example, farmers can remove animals from low-lying areas and utility services can put in place emergency provisions to re-route services if needed. Emergency services can also make provisions to have enough resources available ahead of time to respond to emergencies as they occur.

In order to make the most accurate flood forecasts for waterways, it is best to have a long time-series of historical data that relates stream flows to measured past rainfall events. Coupling this historical information with real-time knowledge about volumetric capacity in catchment areas, such as spare capacity in reservoirs, ground-water levels, and the degree of saturation of area aquifers is also needed in order to make the most accurate flood forecasts.

Radar estimates of rainfall and general climate forecasting techniques are also important components of good flood forecasting. In areas where good quality data are available, the intensity and height of a flood can be predicted with fairly good accuracy and plenty of lead time. The output of a flood forecast is typically a maximum expected water level and the likely time of its arrival at key locations along a waterway, and it also may allow for the computation of the likely statistical return period of a flood. In many developed countries, urban areas at risk of flooding protect against a 100-year flood - that is a flood that has a probability of around 63% of occurring in any 100 year period of time.

According to the U.S. National Climate Service (NWS) Northeast River Forecast Center (RFC) in Taunton, Massachusetts, a general rule-of-thumb for flood forecasting in urban areas is that it takes at least 1 inch (25 mm) of rainfall in around an hour's time in order to start important ponding of water on impermeable surfaces. Many NWS RFCs routinely issue Flash Flood Guidance and Headwater Guidance, which indicate the general amount of rainfall that would need to fall in a short period of time in order to cause flash flooding or flooding on larger water basins.

3.2•3.4 Control

In many countries around the world, waterways prone to floods are often carefully managed. Defenses such as detention basins, levees, bunds, reservoirs, and weirs are used to prevent waterways from overflowing their banks. When these defenses fail, emergency measures such as sandbags or portable inflatable tubes are often used to try and stem flooding. Coastal flooding has been addressed in portions of Europe and the Americas with coastal defenses, such as sea walls, beach nourishment, and barrier islands.

In the riparian zone near rivers and streams, erosion control measures can be taken to try and slow down or reverse the natural forces that cause many waterways to meander over long periods of time. Flood controls, such as dams, can be built and maintained over time to try and reduce the occurrence and severity of floods as well. In the USA, the U.S. Army Corps of Engineers maintains a network of such flood control dams.

In areas prone to urban flooding, one solution is the repair and expansion of man-made sewer systems and stormwater infrastructure. Another strategy is to reduce impervious surfaces in streets, parking lots and buildings through natural drainage channels, porous paving, and wetlands (collectively known as green infrastructure or sustainable urban drainage systems [SUDS]). Areas identified as flood-prone can be converted into parks and playgrounds that can tolerate occasional flooding. Ordinances can be adopted to require developers to retain stormwater on site and require buildings to be elevated, protected by floodwalls and levees, or designed to withstand temporary inundation. Property owners can also invest in solutions themselves, such as re-landscaping their property to take the flow of water away from their building and installing rain barrels, sump pumps, and check valves.

3.2•3.5 Benefits

Floods (in particular more frequent or smaller floods) can also bring many benefits, such as recharging ground water, making the soil more fertile and increasing nutrients in some soils. Flood waters provide much needed water resources in arid and semi-arid regions where precipitation can be very unevenly distributed throughout the year. Freshwater floods particularly play an important role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biovariety. Flooding can spread nutrients to lakes and rivers, which can lead to increased biomass and improved fisheries for a few years.

For some fish species, an inundated floodplain may form a highly suitable location for spawning with few predators and enhanced levels of nutrients or food. Fish, such as the climate fish, make use of floods in order to reach new habitats. Bird populations may also profit from the boost in food production caused by flooding.

Periodic flooding was essential to the well-being of ancient communities along the Tigris-Euphrates Rivers, the Nile River, the Indus River, the Ganges and the Yellow River among others. The viability of hydropower, a renewable source of energy, is also higher in flood prone regions.

3.2•3.6 Computer modelling

While flood computer modeling is a fairly recent practice, attempts to understand and manage the mechanisms at work in floodplains have been made for at least six millennia. Recent developments in computational flood modeling have enabled engineers to step away from the tried and tested "hold or break" approach and its tendency to promote overly engineered structures. Various computational flood models have been developed in recent years; either 1D models (flood levels measured in the channel) or 2D models (variable flood depths measured across the extent of a floodplain). HEC-RAS, the Hydraulic Engineering Centre model, is currently among the most popular computer models, if only because it is available free of charge. Other models such as TUFLOW combine 1D and 2D components to derive flood depths across both river channels and the entire floodplain. To date, the focus of computer modelling has primarily been on mapping tidal and fluvial flood events, but the 2007 flood events in the UK have shifted the emphasis there onto the impact of surface water flooding.

In the United States, an integrated approach to real-time hydrologic computer modeling utilizes observed data from the U.S. Geological Survey (USGS), various cooperative observing networks, various automated climate sensors, the NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC), various hydroelectric companies, etc. Combined with quantitative precipitation forecasts (QPF) of expected rainfall and/or snow melt to generate daily or as-needed hydrologic forecasts. The NWS also cooperates with Environment Canada on hydrologic forecasts that affect both the USA and Canada, like in the area of the Saint Lawrence Seaway.

3.3 Green House effect & Global Warming

3.3.1 Greenhouse effect

The **greenhouse effect** is a procedure by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases.

Solar radiation at the frequencies of visible light largely passes through the atmosphere to warm the planetary surface, which then emits this energy at the lower frequencies of infrared thermal radiation. Infrared radiation is absorbed by greenhouse gases, which in turn re-radiate much of the energy to the surface and lower atmosphere. The mechanism is named after the effect of solar radiation passing through glass and warming a greenhouse, but the way it retains heat is fundamentally different as a greenhouse works by reducing airflow, isolating the warm air inside the structure so that heat is not lost by convection.

If an ideal thermally conductive blackbody was the same distance from the Sun as the Earth is, it would have a temperature of about 5.3 °C. However, since the Earth reflects about 30% of the incoming sunlight, this idealized planet's effective temperature (the temperature of a blackbody that would emit the same amount of radiation) would be about −18 °C. The surface temperature of this hypothetical planet is 33 °C below the Earth's actual surface temperature of approximately 14 °C. The mechanism that produces this difference between the actual surface temperature and the effective temperature is due to the atmosphere and is known as the greenhouse effect.

The earth’s natural greenhouse effect makes life as we know it possible. However, human activities, primarily the burning of fossil fuels and clearing of forests, have intensified the natural greenhouse effect, causing global warming.

3.3.1.1 History

The existence of the greenhouse effect was argued for by Joseph Fourier in 1824. The argument and the evidence were further strengthened by Claude Pouillet in 1827 and 1838, and reasoned from experimental observations by John Tyndall in 1859, and more fully quantified by Svante Arrhenius in 1896.

In 1917 Alexander Graham Bell wrote “[The unchecked burning of fossil fuels] would have a sort of greenhouse effect”, and “The net result is the greenhouse becomes a sort of hot-house.” Bell went on to also advocate for the use of alternate energy sources, such as solar energy.

3.3.1.2 Mechanism

The Earth receives energy from the Sun in the form UV, visible, and near IR radiation, most of which passes through the atmosphere without being absorbed. Of the total amount of energy available at the top of the atmosphere (TOA), about 50% is absorbed at the Earth's surface. Because it is warm, the surface radiates far IR thermal radiation that consists of wavelengths that are predominant much longer than the wavelengths that were absorbed (the overlap between the incident solar spectrum and the terrestrial thermal spectrum is small enough to be neglected for most purposes). Most of this thermal radiation is absorbed by the atmosphere and re-radiated both upwards and downwards; that radiated downwards is absorbed by the Earth's surface. This trapping of long-wavelength thermal radiation leads to a higher equilibrium temperature than if the atmosphere were absent.

This highly simplified picture of the basic mechanism needs to be qualified in a number of ways, none of which affects the fundamental procedure.

- The incoming radiation from the Sun is mostly in the form of visible light and nearby wavelengths, largely in the range 0.2–4 μm, corresponding to the Sun's radiative temperature of 6,000 K. Almost half the radiation is in the form of "visible" light, which our eyes are adapted to use.
- About 50% of the Sun's energy is absorbed at the Earth's surface and the rest is reflected or absorbed by the atmosphere. The reflection of light back into space—largely by clouds—does not much affect the basic mechanism; this light, effectively, is lost to the system.
- The absorbed energy warms the surface. Simple presentations of the greenhouse effect, such as the idealized greenhouse model, show this heat being lost as thermal radiation. The reality is more complex: the atmosphere near the surface is largely opaque to thermal radiation (with important exceptions for "window" bands), and most heat loss from the surface is by sensible heat and latent heat transport. Radiative energy losses become increasingly important higher in the atmosphere largely because of the decreasing concentration of water vapor, an important greenhouse gas. It is more realistic to think of the greenhouse effect as applying to a "surface" in the mid-troposphere, which is effectively coupled to the surface by a lapse rate.
- The simple picture assumes a steady state. In the real world there is the diurnal cycle as well as seasonal cycles and climate. Solar heating only applies during daytime. During the night, the atmosphere cools somewhat, but not greatly, because its emissivity is low, and during the day the atmosphere warms. Diurnal temperature changes decrease with height in the atmosphere.
- Within the region where radiative effects are important the description given by the idealized greenhouse model becomes realistic: The surface of the Earth, warmed to a temperature around 255 K, radiates long-wavelength, infrared heat in the range 4–100 μm. At these wavelengths, greenhouse gases that were largely transparent to incoming solar radiation are more absorbent. Each layer of atmosphere with greenhouse gases absorbs some of the heat being radiated upwards from lower layers. It re-radiates in all directions, both upwards and downwards; in equilibrium (by definition) the same amount as it has absorbed. This results in more warmth below. Increasing the concentration of the gases increases the amount of absorption and re-radiation, and thereby further warms the layers and ultimately the surface below.
- Greenhouse gases—including most diatomic gases with two different atoms (such as carbon monoxide, CO) and all gases with three or more atoms—are able to absorb and emit infrared radiation. Though more than 99% of the dry atmosphere are IR transparent (because the main constituents—N_2, O_2, and Ar—are not able to directly absorb or emit infrared radiation), intermolecular collisions cause the energy absorbed and emitted by the greenhouse gases to be shared with the other, non-IR-active, gases.

3.3.1.3 **Greenhouse gases**

By their percentage contribution to the greenhouse effect on Earth the four major gases are:

- Water vapor, 36–70%
- Carbon dioxide, 9–26%
- Methane, 4–9%
- Ozone, 3–7%

The major non-gas contributor to the Earth's greenhouse effect, clouds, also absorb and emit infrared radiation and thus have an effect on radiative properties of the atmosphere.

3.3.1.4 **Role in climate change**

Strengthening of the greenhouse effect through human activities is known as the enhanced (or anthropogenic) greenhouse effect. This increase in radiative forcing from human activity is attributable mainly to increased atmospheric carbon dioxide levels. According to the latest Assessment Report from the Intergovernmental Panel on Climate Change, "*most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations*".

CO_2 is produced by fossil fuel burning and other activities such as cement production and tropical deforestation. Measurements of CO_2 from the Mauna Loa observatory show that concentrations have increased from about 313 ppm in 1960 to about 389 ppm in 2010. It reached the 400ppm milestone on May 9, 2013. The current observed amount of CO_2 exceeds the geological record maxima (~300 ppm) from ice core data. The effect of combustion-produced carbon dioxide on the global climate, a special case of the greenhouse effect first described in 1896 by Svante Arrhenius, has also been called the Callendar effect.

Over the past 800,000 years, ice core data shows that carbon dioxide has varied from values as low as 180 parts per million (ppm) to the pre-industrial level of 270ppm. Paleoclimatologists consider variations in carbon dioxide concentration to be a fundamental factor influencing climate variations over this time scale.

3.3.1.5 Real greenhouses

The "greenhouse effect" of the atmosphere is named by analogy to greenhouses which get warmer in sunlight, but the mechanism by which the atmosphere retains heat is different. A greenhouse works primarily by preventing absorbed heat from leaving the structure through convection, i.e. sensible heat transport. The greenhouse effect heats the earth because greenhouse gases absorb outgoing radiative energy and re-emit some of it back towards earth.

A greenhouse is built of any material that passes sunlight, usually glass, or plastic. It mainly heats up because the Sun warms the ground inside, which then warms the air in the greenhouse. The air continues to heat because it is confined within the greenhouse, unlike the environment outside the greenhouse where warm air near the surface rises and mixes with cooler air aloft. This can be demonstrated by opening a small window near the roof of a greenhouse: the temperature will drop considerably. It has also been demonstrated experimentally (R. W. Wood, 1909) that a "greenhouse" with a cover of rock salt (which is transparent to infra red) heats up an enclosure similarly to one with a glass cover. Thus greenhouses work primarily by preventing convective cooling.

In the greenhouse effect, rather than retaining (sensible) heat by physically preventing movement of the air, greenhouse gases act to warm the Earth by re-radiating some of the energy back towards the surface. This procedure may exist in real greenhouses, but is comparatively unimportant there.

3.3.1.6 Bodies other than Earth

In the Solar System, Mars, Venus, and the moon Titan also exhibit greenhouse effects; that on Venus is particularly large, due to its atmosphere, which consists mainly of dense carbon dioxide Titan has an anti-greenhouse effect, in that its atmosphere absorbs solar radiation but is relatively transparent to infrared radiation. Pluto also exhibits behavior superficially similar to the anti-greenhouse effect.

A runaway greenhouse effect occurs if positive feedbacks lead to the evaporation of all greenhouse gases into the atmosphere. A runaway greenhouse effect involving carbon dioxide and water vapor is thought to have occurred on Venus.

3.3.2 **Global Warming**

Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation. Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C (1.4 °F), with about two-thirds of the increase occurring since 1980. Warming of the climate system is unequivocal, and scientists are more than 90% certain that it is primarily caused by increasing concentrations of greenhouse gases produced by human activities such as the burning of fossil fuels and deforestation. These findings are recognized by the national science academies of all major industrialized nations.

Climate model projections were summarized in the 2007 Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC). They indicated that during the 21st century the global surface temperature is likely to rise a further 1.1 to 2.9 °C (2 to 5.2 °F change) for their lowest emissions scenario and 2.4 to 6.4 °C (4.3 to 11.5 °F change) for their highest. The ranges of these estimates arise from the use of models with differing sensitivity to greenhouse gas concentrations.

Future climate change and associated impacts will vary from region to 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 and would be associated with the continuing retreat of glaciers, permafrost and sea ice. Other likely effects of the warming include a more frequent occurrence of extreme climate events including heat waves, droughts and heavy rainfall, ocean acidification and species extinctions due to shifting temperature regimes. Effects important to humans include the threat to food security from decreasing crop yields and the loss of habitat from inundation.

Proposed policy responses to global warming include mitigation by emissions reduction, adaptation to its effects, and possible future geoengineering. Most countries are parties to the United Nations Framework Convention on Climate Change (UNFCCC), whose ultimate objective is to prevent dangerous anthropogenic (i.e., human-induced) climate change. Parties to the UNFCCC have adopted a range of policies designed to reduce greenhouse gas emissions and to assist in adaptation to global warming. Parties to the UNFCCC have agreed that deep cuts in emissions are required, and that future global warming should be limited to below 2.0 °C (3.6 °F) relative to the pre-industrial level. Reports published in 2011 by the United Nations Environment Program and the International Energy Agency suggest that efforts as of the early 21st century to reduce emissions may be inadequate to meet the UNFCCC's 2 °C target.

3.3.2.1 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 double that for the period as a whole (0.13±0.03 °C per decade, versus 0.07±0.02 °C per decade). The urban heat 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, according to satellite temperature measurements. Climate proxies 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 systematic 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 of spring events, e.g., the flowering of plants. The probability that these changes could have occurred by chance is virtually zero.

Recent estimates by NASA's Goddard Institute for Space Studies (GISS) and the National Climatic Data Center show that 2005 and 2010 tied for the planet's warmest year since reliable, widespread instrumental measurements became available in the late 19th century, exceeding 1998 by a few hundredths of a degree. Estimates by the Climatic Research Unit (CRU) show 2005 as the second warmest year, behind 1998 with 2003 and 2010 tied for third warmest year, however, "the error estimate for individual years ... is at least ten times larger than the differences between these three years." The World Meteorological Organization (WMO) *statement on the status of the global climate in 2010* explains that, "The 2010 nominal value of +0.53 °C ranks just ahead of those of 2005 (+0.52 °C) and 1998 (+0.51 °C), although the differences between the three years are not statistically important..." Every year from 1986 to 2012 has seen world annual mean temperatures above the 1961-1990 average.

Temperatures in 1998 were unusually warm because global temperatures are affected by the El Niño-Southern Oscillation (ENSO), and the strongest El Niño in the past century occurred during that year. The global temperature is subject to short-term fluctuations that overlay long term trends and can temporarily mask them. The relative stability in temperature from 2002 to 2009 is consistent with such an episode. 2010 was also an El Niño year. On the low swing of the oscillation, 2011 as a La Niña year was cooler but it was still the 11th warmest year since records began in 1880. Of the 13 warmest years since 1880, 11 were the years from 2001 to 2011. Over the more recent record, 2011 was the warmest La Niña year in the period from 1950 to 2011, and was close to 1997 which was not at the lowest point of the cycle.

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 petawatts 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 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.

3.3.2.2 **Initial causes of temperature changes (external forcing)**

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. Orbital 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.

3.3.2.3 Greenhouse gases

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

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 stable through cloud forcing similar of greenhouse gases.

Human activity since the Industrial Revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radiative forcing from CO_2, methane, tropospheric ozone, CFCs and nitrous oxide. According to work published in 2007, the concentrations of CO_2 and methane have increased by 36% and 148% respectively since 1750. These levels are much higher than at any time during the last 800,000 years, the period for which reliable data has been extracted from ice cores. Less direct geological evidence indicates that CO_2 values higher than this were last seen about 20 million years ago. Fossil fuel burning has produced about three-quarters of the increase in CO_2 from human activity over the past 20 years. The rest of this increase is caused mostly by changes in land-use, particularly deforestation. Estimates of global CO_2 emissions in 2011 from fossil fuel combustion, including cement production and gas flaring, was 34.8 billion tonnes (9.5 ± 0.5 PgC), an increase of 54% above emissions in 1990. Coal burning was responsible for 43% of the total emissions, oil 34%, gas 18%, cement 4.9% and gas flaring 0.7% In May 2013, it was reported that readings for CO_2 taken at the world's primary benchmark site in Mauna Loa surpassed 400 ppm. According to professor Brian Hoskins, this is likely the first time CO_2 levels have been this high for about 4.5 million years.

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 scenarios, estimates of changes in future emission levels of greenhouse gases, have been projected that depend upon uncertain economic, sociological, technological, and natural developments. In most scenarios, emissions continue to rise over the century, while in a few, emissions are reduced. Fossil fuel reserves are abundant, and will not limit carbon emissions in the 21st century. Emission scenarios, combined with modelling of the carbon cycle, have been used to produce estimates of how atmospheric concentrations of greenhouse gases might change in the future. Using the six IPCC SRES "marker" scenarios, models suggest that by the year 2100, the atmospheric concentration of CO_2 could range between 541 and 970 ppm. This is an increase of 90–250% above the concentration in the year 1750.

The popular media and the public often confuse global warming with ozone depletion, i.e., the destruction of stratospheric ozone by chlorofluorocarbons. Although there are a few areas of linkage, the relationship between the two is not strong. Reduced stratospheric ozone has had a slight cooling influence on surface temperatures, while increased tropospheric ozone has had a somewhat larger warming effect.

3.3.2.4 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 aerosols – have largely 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. Radiative forcing due to particulates is temporally limited due to wet deposition which causes them to have an atmospheric lifetime 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.

In addition to their direct effect by scattering and absorbing solar radiation, particulates have indirect effects on the Earth's radiation budget. Sulfates act as cloud condensation nuclei and thus lead to clouds that have more and smaller cloud droplets. These clouds reflect solar radiation more efficiently than clouds with fewer and larger droplets, known as the Twomey effect. This effect also causes droplets to be of more uniform size, which reduces growth of raindrops and makes the cloud more reflective to incoming sunlight, known as the Albrecht effect. Indirect effects are most noticeable in marine stratiform clouds, and have a very little radioactive effect on convective clouds. Indirect effects of particulates represent the largest uncertainty in radiative forcing.

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. When deposited, especially on glaciers or on ice in arctic regions, the lower surface albedo can also directly heat the surface. The influences of particulates, including black carbon, are most pronounced in the tropics and sub-tropics, particularly in Asia, while the effects of greenhouse gases are dominant in the extratropics and the southern hemisphere.

3.3.2.5 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. In the three decades since 1978, the combination of solar and volcanic activity probably had a slight cooling influence on the climate.

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 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 forcings.

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. If the sun were responsible for observed warming, warming of both the troposphere and stratosphere would be expected.

3.3.2.6 Feedback

The climate system includes a range of *feedbacks* which alter the response of the system to changes in external forcing. Positive feedbacks increase the response of the climate system to an initial forcing, while negative feedbacks reduce the response of the climate system to an initial forcing.

There are a range of feedbacks in the climate system, including water vapor, changes in ice-albedo (snow and ice cover affect how much the Earth's surface absorbs or reflects incoming sunlight), clouds, and changes in the Earth's carbon cycle (e.g., the release of carbon from soil). The main negative feedback is the energy which the Earth's surface radiates into space as infrared radiation. According to the Stefan-Boltzmann law, if temperature doubles, radiated energy increases by a factor of 16 (2 to the 4th power).

Feedbacks are an important factor in determining the sensitivity of the climate system to increased atmospheric greenhouse gas concentrations. Other factors being equal, a higher *climate sensitivity* means that more warming will occur for a given increase in greenhouse gas forcing. Uncertainty over the effect of feedbacks is a major reason why different climate models project different magnitudes of warming for a given forcing scenario. More research is needed to understand the role of clouds and carbon cycle feedbacks in climate projections.

The IPCC projections given in the lede span the "likely" range (greater than 66% probability, based on expert judgement) for the selected emissions scenarios. However, the IPCC's projections do not reflect the full range of uncertainty. The lower end of the "likely" range appears to be better constrained than the upper end of the "likely" range.

3.3.2.7 Climate models

A climate model is a computerized representation of the five components of the climate system: Atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Such models are based on systematic disciplines such as fluid dynamics, thermodynamics as well as physical procedures such as radiative transfer. 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 procedures; solar variability and others.

Although researchers attempt to include as many procedures as possible, simplifications of the actual climate system are inevitable because of the constraints of available computer power and limitations in knowledge of the climate system. Results from models can also vary due to different greenhouse gas inputs and the model's climate sensitivity. For example, the uncertainty in IPCC's 2007 projections is caused by (1) the use of multiple models with differing sensitivity to greenhouse gas concentrations, (2) the use of differing estimates of humanity's future greenhouse gas emissions, (3) any additional emissions from climate feedbacks that were not included in the models IPCC used to prepare its report, i.e., greenhouse gas releases from permafrost.

The models do not assume the climate will warm due to increasing levels of greenhouse gases. Instead the models predict how greenhouse gases will interact with radiative transfer and other physical procedures. One of the mathematical results of these complex equations is a prediction whether warming or cooling will occur.

Recent research has called special attention to the need to refine models with respect to the effect of clouds and the carbon cycle.

Models are also used to help investigate the causes of recent climate change by comparing the observed changes to those that the models project from various natural and human-derived causes. Although these models do not unambiguously attribute the warming that occurred from approximately 1910 to 1945 to either natural variation or human effects, they do indicate that the warming since 1970 is dominated by man-made greenhouse gas emissions.

The physical realism of models is tested by examining their ability to simulate contemporary or past climates. Climate models produce a good match to observations of global temperature changes over the last century, but do not simulate all aspects of climate. Not all effects of global warming are accurately predicted by the climate models used by the IPCC. Observed Arctic shrinkage has been faster than that predicted. Precipitation has increased proportionally to atmospheric humidity, and hence importantly faster than global climate models predict.

3.3.2.8 Observed and expected environmental effects

"Detection" is the procedure of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change. The detection does not imply attribution of the detected change to a particular cause. "Attribution" of causes of climate change is the procedure 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.

3.3.2.9 Natural systems

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 does not provide a best estimate of global mean sea level rise, and their upper estimate 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.

Widespread coastal flooding would be expected if several degrees of warming are sustained for millennia. For example, sustained global warming of more than 2 °C (relative to pre-industrial levels) could lead to eventual sea level rise of around 1 to 4 m due to thermal expansion of sea water and the melting of glaciers and small ice caps. Melting of the Greenland ice sheet could contribute an additional 4 to 7.5 m over many thousands of years.

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, glaciers 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 km) as early as 2025-2030.

Future changes in precipitation are expected to follow existing trends, with reduced precipitation over subtropical land areas, and increased precipitation at subpolar latitudes and some equatorial regions. Projections suggest a probable increase in the frequency and severity of some extreme climate events, such as heat waves.

3.3.2.10 Ecological systems

In terrestrial ecosystems, the earlier timing of spring events, and poleward 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 variety of ecosystems.

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 an 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.

3.3.2.11 Large-scale and abrupt impacts

Climate change could result in global, large-scale changes in natural and social systems. Two examples are ocean acidification 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 from permafrost, which would lead to amplified global warming. Systematic 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.

3.3.2.12 Observed and expected effects on social systems

The vulnerability of human societies to climate change mainly lies in the effects of extreme climate 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. Most economic studies suggest that global warming would reduce world gross domestic product (GDP).

3.3.2.12.1 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.

3.3.2.12.2 Habitat inundation

In small islands and megadeltas, 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.

3.3.2.12.3 Proposed policy responses to global warming

There are different views over what the appropriate policy response to climate change should be. These competing views weigh the benefits of limiting emissions of greenhouse gases against the costs. In general, it seems likely that climate change will impose greater damages and risks in poorer regions.

3.3.2.13 Mitigation

Reducing the amount of future climate change is called mitigation of climate change. The IPCC defines mitigation as activities that reduce greenhouse gas (GHG) emissions, or enhance the capacity of carbon sinks to absorb GHGs from the atmosphere. Studies indicate substantial potential for future reductions in emissions by a combination of emission-reducing activities such as energy conservation, increased energy efficiency, and satisfying more of society's power demands with renewable energy and/or nuclear energy sources. Climate mitigation also includes acts to enhance natural sinks, such as reforestation.

In order to limit warming to within the lower range described in the IPCC's "Summary Report for Policymakers" it will be necessary to adopt policies that will limit greenhouse gas emissions to one of several important different scenarios described in the full report. This will become more and more difficult with each year of increasing volumes of emissions and even more drastic measures will be required in later years to stabilize a desired atmospheric concentration of greenhouse gases. Energy-related carbon-dioxide (CO2) emissions in 2010 were the highest in history, breaking the prior record set in 2008.

3.3.2.14 Adaptation

Other policy responses include adaptation to climate change. Adaptation to climate change may be planned, either in reaction to or anticipation of climate change, or spontaneous, i.e., without government intervention. Planned adaptation is already occurring on a limited basis. The barriers, limits, and costs of future adaptation are not fully understood.

A theory related to adaptation is "adaptive capacity", which is the ability of a system (human, natural or managed) to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Unmitigated climate change (i.e., future climate change without efforts to limit greenhouse gas emissions) would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt.

Ecological organizations and public figures have emphasized changes in the climate and the risks they entail, while promoting adaptation to changes in infrastructural needs and emissions reductions.

3.4 Theory of Sustainable Development.

Sustainable development refers to a mode of human development in which resource use aims to meet human needs while ensuring the sustainability of natural systems and the environment, so that these needs can be met not only in the present, but also for generations to come. The term 'sustainable development' was used by the Brundtland Commission, which coined what has become the most often-quoted definition of sustainable development: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges faced by humanity. As early as the 1970s, "sustainability" was employed to describe an economy "in equilibrium with basic ecological support systems." Ecologists have pointed to *The Limits to Growth*, and presented the alternative of a "steady state economy" in order to address environmental concerns.

The theory of sustainable development has in the past most often been broken out into three constituent parts: ecological sustainability, economic sustainability and sociopolitical sustainability. More recently, it has been suggested that a more consistent analytical breakdown is to distinguish four domains of economic, ecological, political and cultural sustainability. This is consistent with the UCLG move to make 'culture' the fourth domain of sustainability. Other important sources refer to the fourth domain as 'institutional' or as 'good governance.'

3.4.1 Definition

In 1987, the United Nations released the Brundtland Report, which included what is now one of the most widely recognized definitions: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

According to the same report, the above definition contains within it two key theories:

- The theory of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and

- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

The United Nations 2005 World Summit Outcome Document refers to the "interdependent and mutually reinforcing pillars" of sustainable development as economic development, social development, and ecological protection. Based on the triple bottom line, numerous sustainability standards and certification systems have been established in recent years, in particular in the food industry. Well-known standards include organic, Rainforest Alliance, fair trade, UTZ Certified, Bird Friendly, and The Common Code for the Coffee Community.

Indigenous people have argued, through various international forums such as the United Nations Permanent Forum on Indigenous Issues and the Convention on Biological Variety, that there are *four* pillars of sustainable development, the fourth being cultural. *The Universal Declaration on Cultural Variety* (UNESCO, 2001) further elaborates the theory by stating that "... Cultural variety is as necessary for humankind as biovariety is for nature"; it becomes "one of the roots of development understood not simply in terms of economic growth, but also as a means to achieve a more satisfactory intellectual, emotional, moral and spiritual existence". In this vision, cultural variety is the fourth policy area of sustainable development.

A useful articulation of the values and principles of sustainability can be found in the Earth Charter. It offers an integrated vision and definition of strong sustainability. The document, an ethical framework for a sustainable world, was developed over several years after the Rio Earth Summit in 1992 and launched officially in 2000. The Charter derives its legitimacy from the participatory procedure in which it was drafted, which included contributions from hundreds of organizations and thousands of individuals, and from its use since 2000 by thousands of organizations and individuals that have been using the Earth Charter as an educational instrument and a policy tool.

Economic Sustainability: Agenda 21 clearly identified information, integration, and participation as key building blocks to help countries achieve development that recognizes these interdependent pillars. It emphasizes that in sustainable development everyone is a user and a provider of information. It stresses the need to change from old sector-centered ways of doing business to new approaches that involve cross-sectoral co-ordination and the integration of ecological and social concerns into all development procedures. Furthermore, Agenda 21 emphasizes that broad public participation in decision making is a fundamental prerequisite for achieving sustainable development.

According to Hasna Vancock, sustainability is a procedure which tells of a development of all aspects of human life affecting sustenance. It means resolving the conflict between the various competing goals, and involves the simultaneous pursuit of economic prosperity, ecological quality and social equity famously known as three dimensions (triple bottom line) with the resultant vector being technology, hence it is a continually evolving procedure; the 'journey' (the procedure of achieving sustainability) is of course vitally important, but only as a means of getting to the destination (the desired future state). However, the 'destination' of sustainability is not a fixed place in the normal sense that we understand the destination. Instead, it is a set of wishful characteristics of a future system.

The theory has included notions of weak sustainability, strong sustainability, deep ecology, and just sustainability Just sustainability effectively addresses what has been called the 'equity deficit' of *environmental* sustainability (Agyeman, 2005:44). It is "the egalitarian theories of sustainable development" (Jacobs, 1999:32). It generates a more nuanced definition of sustainable development: "the need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems" (Agyeman, et al., 2003:5). This theory of sustainable development focuses equally on four conditions: improving our quality of life and well-being; on meeting the needs of both present and future generations (intra- and intergenerational equity); on justice and equity in terms of recognition (Schlosberg, 1999), procedure, procedure and the outcome and on the need for us to live within ecosystem limits (also called one planet living) (Agyeman, 2005:92). Open-source appropriate technology has been proposed as an approach for reaching just sustainable development.

Green development is generally differentiated from sustainable development in that Green development prioritizes what its proponents consider to be ecological sustainability over economic and cultural considerations. Proponents of Sustainable Development argue that it provides a context in which to improve overall sustainability where cutting edge Green Development is unattainable. For example, a cutting edge treatment plant with extremely high maintenance costs may not be sustainable in regions of the world with fewer financial resources. An environmentally ideal plant that is shut down due to bankruptcy is obviously less sustainable than one that is maintained by the community, even if it is somewhat less effective from an ecological standpoint. However, this view depends on whether one determines that it is the development (the plant) which needs to be sustainable, or whether it is the human-nature ecology (the environmental conditions) in which the plant exists which should be sustainable. It follows, then, that an operational but heavily polluting plant may be judged as actually 'less sustainable' than having no plant at all.

Sustainability educator Michael Thomas Needham referred to 'Sustainable Development' "as the ability to meet the needs of the present while contributing to the future generations’ needs." There is an additional focus on the present generations' responsibility to improve the future generations' life by restoring the previous ecosystem damage and resisting to contribute to further ecosystem damage.

3.4.2 National difference

An international survey found that attitudes to sustainable development differ in 12 participating nations (China, Czech, Spain, Ireland, Korea, Macedonia, Norway, Portugal, Sweden, Serbia, United Kingdom). The perceived importance is lower in Czech, Ireland, Iran and South Korea.

3.4.3 Domains

3.4.4 Economics

The domain of 'economics' is fundamental to considerations of sustainable development, however there has been considerable criticism of the tendency to use the three-domain model of the triple bottom line: economics, environment and social. This approach is challenged to the extent that it treats the economy as the master domain, or as a domain that exists outside of the social; it treats the environment as a world of natural metrics; and it treats the social as a miscellaneous collection of extra things that do not fit into the economic or ecological domains. In the alternative Circles of Sustainability approach, the economic domain is defined as the practices and meanings associated with the production, use, and management of resources, where the theory of ‘resources’ is used in the broadest sense of that word.

3.4.5 Ecology

The domain of 'ecology' has been difficult to resolve because it too has a social dimension. Some research activities start from the definition of green development to argue that the environment is a combination of nature and culture. However, this has the effect of making the domain model unwieldy if culture is to be considered a domain in its own right. Others write about ecology as being more broadly at the intersection of the social and the ecological - hence, ecology. This move allows culture to be used as a domain alongside economics and ecology.

The sustainability of human settlements is implicit in the focus of study into the relationship between humans and their natural, social and built environments. Also termed human ecology, this broadens the focus of sustainable development to include the domain of human health. Fundamental human needs such as the availability and quality of air, water, food and shelter are also the ecological foundations for sustainable development; addressing public health risk through investments in ecosystem services can be a powerful and transformative force for sustainable development which, in this sense, extends to all species.

3.4.6 Culture

Working with a different emphasis, some researchers and institutions have pointed out that a fourth dimension should be added to the dimensions of sustainable development, since the triple-bottom-line dimensions of economic, ecological and social do not seem to be enough to reflect the complexity of contemporary society. In this context, the Agenda 21 for culture and the United Cities and Local Governments (UCLG) Executive Bureau lead the preparation of the policy statement “Culture: Fourth Pillar of Sustainable Development”, passed on 17 November 2010, in the framework of the World Summit of Local and Regional Leaders – 3rd World Congress of UCLG, held in Mexico City. This document inaugurates a new perspective and points to the relation between culture and sustainable development through a dual approach: developing a solid cultural policy and advocating a cultural dimension in all public policies. The Network of Excellence "Sustainable Development in a Diverse World", sponsored by the European Union, integrates multidisciplinary capacities and interprets cultural variety as a key element of a new strategy for sustainable development. The Circles of Sustainability approach define the cultural domain as practices, discourses, and material expressions, which, over time, express continuities and discontinuities of social meaning. However, culture falls within the social/sociopolitical dimension of sustainability, and therefore the proposal for adding a fourth "cultural" dimension has not been widely accepted.

3.4.7 Politics

The United Nations Global Compact Cities Program has defined sustainable political development is a way that broadens the usual definition beyond states and governance. The political is defined as the domain of practices and meanings associated with basic issues of social power as they pertain to the organization, authorization, legitimation and regulation of a social life held in common. This definition is in accord with the view that political change is important for responding to economic, ecological and cultural challenges. It also means that the politics of economic change can be addressed. This is particularly true in relation to the controversial theory of 'sustainable enterprise' that frames global needs and risks as 'opportunities' for private enterprise to provide profitable entrepreneurial solutions. This theory is now being taught in many business schools including the Center for Sustainable Global Enterprise at Cornell University and the Erb Institute for Global Sustainable Enterprise at the University of Michigan.

Sustainable development is an eclectic theory and a wide array of political views fall under its umbrella. The theory has included notions of weak sustainability, strong sustainability and deep ecology. Different concepts also reveal a strong tension between ecocentrism and anthropocentrism. Many definitions and images (Visualizing Sustainability) of sustainable development co-exist. Broadly defined, the sustainable development mantra enjoins current generations to take a systems approach to growth and development and to manage natural, produced, and social capital for the welfare of their own and future generations.

During the last ten years, different organizations have tried to measure and monitor the proximity to what they consider sustainability by implementing what has been called sustainability metrics and indices. This has engendered considerable political debate about what is being measured. Sustainable development is said to set limits on the developing world. While current first world countries polluted importantly during their development, the same countries encourage third world countries to reduce pollution, which sometimes impedes growth. Some consider that the implementation of sustainable development would mean a reversion to pre-modern lifestyles.

So its our prime duty to sustain the resources for further generation as by doing so they can learn from us.... :)

Others have criticized the overuse of the term:

> "[The] word sustainable has been used in too many situations today, and ecological sustainability is one of those terms that confuse a lot of people. You hear about sustainable development, sustainable growth, sustainable economies, sustainable societies, sustainable agriculture. Everything is sustainable (Temple, 1992)."

3.4.8 History of the theory

The theory of sustainable development was originally synonymous with that of sustainability and is often still used in that way. Both terms derive from the older forestry term "sustained yield", which in turn is a translation of the German term "nachhaltiger Ertrag" dating from 1713. According to different sources, the theory of sustainability in the sense of a stable between resource consumption and reproduction was however applied to forestry already in the 12th to the 16th century.

'Sustainability' is a semantic modification, extension and transfer of the term 'sustained yield'. This had been the doctrine and, indeed, the 'holy grail' of foresters all over the world for more or less two centuries. The essence of 'sustained yield forestry' was described for example by William A. Duerr, a leading American expert on forestry: "To fulfill our obligations to our descendents and to stabilize our communities, each generation should sustain its resources at a high level and hand them along undiminished. The sustained yield of timber is an aspect of man's most fundamental need: to sustain life itself." A fine anticipation of the Brundtland-formula.

Not just the theory of sustainable development, but also its current interpretations have its roots in forest management. *Strong* sustainability stipulates living solely off the importance of natural capital, whereas adherents of *weak* sustainability are content to keep stable the sum of natural and human capital.

The history of the theory of sustainability is however much older. Already in 400 BCE, Aristotle referred to a similar Greek theory in talking about household economy. This Greek household theory differed from modern ones in that the household had to be self-sustaining at least to a certain extent and could not just be consumption oriented.

The first use of the term "sustainable" in the modern sense was by the Club of Rome in March 1972 in its epoch-making report on the "Limits to Growth", written by a group of scientists led by Dennis and

Donella Meadows of the Massachusetts Institute of Technology. Describing the desirable "state of global equilibrium", the authors used the word "sustainable": "*We are searching for a model output that represents a world system that is: 1. Sustainable without sudden and uncontrolled collapse; and 2. Capable of satisfying the basic material requirements of all of its people*."

3.4.9 Environmental sustainability

Environmental sustainability is the procedure of making sure current procedures of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behavior. Thus, ecological sustainability demands that society designs activities to meet human needs while indefinitely preserving the life support systems of the planet. This, for example, entails using water sustainably, only utilizing renewable energy, and sustainable material supplies (e.g. harvesting wood from forests at a rate that maintains the biomass and biovariety).

An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. Inherently the theory of sustainable development is intertwined with the theory of carrying capacity. Theoretically, the long-term result of ecological degradation is the inability to sustain human life. Such degradation on a global scale should imply extinction for humanity.

Consumption of renewable resources	State of environment	Sustainability
More than nature's ability to replenish	Ecological degradation	Not sustainable
Equal to nature's ability to replenish	Ecological equilibrium	Steady state economy
Less than nature's ability to replenish	Ecological renewal	Ecologically sustainable

Review Questions

1. Define the Atmospheric Hazards?
2. Explain the Cyclone, Drought, Floods?
3. Explain the Green House effect?
4. Explain the Sustainable Development?

Discussion Questions

Discuss the Global Warming?

Chapter4 - Terrestrial Hazards

Learning Objectives

- To define Terrestrial Hazards.
- To explain the major natural hazards.
- To explain the Man- Induced Hazards.
- To describe the Desertification.

4.1 Terrestrial Hazards

Earthly hazards have clearly left their marks in the history of our civilizations, causing deaths measured by several hundred millions. A distinction must be made between hazards caused by living organisms, at the first rank of which are human beings, and those caused by the 'inert' world or natural hazards which are due to the physical perturbations affecting the solid Earth, the oceans and the atmosphere. In the first category we find wars, which are a fact of humans only, and diseases, both communicable and non-communicable. In the second, we find the seismic-related hazards (volcanoes, earthquakes and tsunamis) and climate-related hazards (storms, floods/landslides and droughts).

4.2 Earthquake, Landslide, Tsunami. Man- Induced Hazards: Causes, Effects & Management.

4.2.1 Earthquake

An earthquake is a tremor in the Earth's crust, caused by movements below its surface. These events can vary widely in intensity, from seismic activity that is barely detectable using sophisticated devices, to devastating temblors that can level cities and trigger tsunamis and sometimes even volcanic activity. The study of these tremors is known as seismology, a word derived from a Greek word meaning "to shake."

The Earth's outer layer, or crust, is composed of two sections: the lithosphere, a Greek word meaning "rocky sphere," and the athenosphere, a thick layer of liquid that rests on top of the upper mantle. The liquid rock of the upper mantle keeps the crust in stable motion, with the edges of continental plates being pulled slowly apart or together as they float on the athenosphere. The movement of these plates is what triggers tremors. In addition to plate boundaries, temblors also occur along faults, cracks in the lithosphere caused by the stresses created as tectonic plates move.

There are a number of different types of faults, but most can be divided into three categories: strike slip faults, thrust faults, and normal faults. A strike slip fault occurs in an area where two plates are sliding past each other, while a thrust fault happens when plates are being pushed together. A normal fault is the result of plates being pulled apart. The largest normal faults in the world are along the deep sea ocean ridges of the Pacific and Atlantic, where plates are pulling apart, crashing into the continental plates and causing thrust faults. Tremors along each fault have different characteristics that help seismologists to identify them.

The roots of a quake lie in stresses placed on the lithosphere as it drifts on the surface of the Earth. Pressure builds up along a fault line, which finally fails, often deep below the crust of the Earth, in an area called the focus. The corresponding spot on the surface of the planet is called the epicenter, and usually the greatest concentration of damage occurs here. When the fault fails, it triggers seismic waves, very low frequency sound waves that come in several shapes, and which can cause the earth to ripple, heave, buckle, or tear apart. The waves can continue for hours after the tremor was triggered, and aftershocks, further smaller tremors, can continue for months and possibly even years later.

The intensity of a tremor is called its magnitude. Various scales were proposed to measure this factor until 1935, when the Richter scale was developed. Under this scale, each order of magnitude is 10 times more intense than the last. A quake that measure a 2 on the Richter scale is 10 times more intense than a 1, while a 3 is 100 times greater. Most quakes around the world are below a 4.5, the magnitude at which it can start to damage buildings, and every year there is at least one greater than an 8, with the largest modern tremor ever recorded occurred in Chile in 1960; it measured at 9.5.

4. 2.1.1 Epicenter

An epicenter is a point on the Earth's crust directly above the focus or hypocenter of a tremor . People often mistakenly refer to the epicenter as the point of origin of a tremor , but in fact this is not the case. The tremor 's origin lies below the surface, with the epicenter being the point on the surface directly above the origin. Tremor damage tends to be most intense at the epicenter, although sometimes a tremor behaves unexpectedly and the damage is heaviest elsewhere.

The hypocenter, also known as the focus, is the place inside the Earth's crust where a rupture occurs as a result of geologic stresses. The movement of a fault at the hypocenter causes a tremendous release of energy which spreads through the Earth, and can vary in magnitude. As one might imagine, the site on the surface directly above the rupture can experience important shaking as a result of the release of energy. Finding the epicenter is important to geologists because it will help them locate the hypocenter, and they can use that information to learn more about that particular tremor as well as tremors in general.

To locate the epicenter, scientists need readings from at least three seismographs in the region. They use the data from each seismograph to determine how far away it was from the epicenter when the tremor occurred, and this data is used to triangulate to find the site on the Earth above the hypocenter. Computer programs are available to do this today, although historically it could be done with a compass and a map, by drawing circles around the location of each seismograph and looking for the point where the circles intersected.

When information about a tremor is released, the data usually include the site of the epicenter. Tremor maps, updated on a regular basis in geologically active regions, show all of the tremors which have occurred within a set period, and point to the location of each epicenter for the convenience of people consulting the maps. Patterns on a tremor map can also reveal trends which may be important, such as increased activity along a particular fault.

Knowing the location of the epicenter can also be important for calamity relief efforts, as it tells people where they should concentrate their energies. It can also be valuable when trying to make predictions about tsunamis and aftershocks, both of which can follow a tremor and endanger relief workers and citizens.

4. 2.1.2 Aftershock

When a tremor hits it might fall into three different classifications. Some tremors are foreshocks and are usually smaller tremors occurring in about the same area as a larger quake will occur later. Others are the big event or a mainshock, which will be the tremor of largest magnitude that occurs. After this large tremor others may follow that are smaller, but still can be dangerous, and these are called aftershocks.

A more specific definition of aftershock is that it is seismic activity representing the earth's readjustment along a fault line after a mainshock event. Such tremors will happen near the mainshock, as do forensics, and could occur for some time after a mainshock event. Usually greatest danger of another tremor with a relatively high magnitude as compared to the mainshock is during the first few days. This danger can exist for several reasons.

With a large main tremor , especially in a well-populated area, structural damage can occur to many different things. A high magnitude aftershock could pose a considerable risk because it might complete the structural damage of certain things. It could cause buildings to collapse, gas lines to break, or other serious problems. It greatly raises the chance of more people losing property or becoming injured. The combined effect of a large mainshock and an only slightly smaller aftershock is sometimes devastating.

One thing that can confuse people is when an aftershock has a higher magnitude rating than a main shock. When this is the case, the whole set of tremors plaguing an area has to be reclassified. Suddenly the aftershock is not "after" any more and becomes the mainshock. The mainshock gets shifted into foreshock status. It may take a while to look at a series of tremor s and determine which one was central, and which were fore and aftershocks.

It's often been noted that recovery from shocks of any kind takes time. This is especially true of aftershocks, which can continue to occur many years after a mainshock happened. Recently it's been suggested that the distance of a tremor from tectonic plates may govern the way land reacts afterwards. If a tremor was far away from tectonic plates, the amount of recovery time from it, could take much longer. For example, some tremors occurring in the US Midwest today are thought to be aftershocks of the ones that occurred in the early 19th century. The earth appears to have a long memory in this theory.

For people who have just encountered a larger tremor , the possibility of experiencing an aftershock should be considered. If a dwelling is unsafe, it ought to be exited until cleared, or if a few things appear to be in disarray, cleaning these quickly is advised. Such times can be difficult to endure and are made more frightening by the potential for additional tremors. Just as the land recovers through these continued tremblers, many people may find themselves desiring recovery time too; aftershocks may be both emotional metaphor and physical expression of the earth.

4. 2.1.3 Magnitude Scale

A magnitude scale is a numerical tool of reference, most often used to describe either the strength of a tremor or the brightness of a star as seen from earth. The scale that is most commonly used to denote the brightness of stars, or their "apparent magnitude," is called the astronomical magnitude scale. For the description of tremors, the Richter scale and the moment magnitude scale are used.

The astronomical magnitude scale defines the magnitude of stars based on the amount of light they give off as perceived by an observer on earth. The higher a star's magnitude number, the dimmer it appears. For example, the brightness of the sun, our closest star, is about a magnitude -26, while the full moon is assigned a magnitude of about -13.

An observer in an urban area will be able to see some stars at night, but none dimmer than a magnitude three. Someone in a rural area can see stars as dim as magnitude six or seven, and binoculars bring the number almost to ten. Telescopes allow us to see much dimmer stars, up to a magnitude 30, in some cases. It is important to note that although the astronomical magnitude scale can be said to measure brightness, a comet of magnitude three will not be as bright as a star of magnitude three, because a comet's light is spread over a larger area.

Those who have lived in tremor -prone areas, or who have studied them to any degree, may be somewhat familiar with the Richter scale, used to measure the magnitude of tremors. The Richter magnitude scale assigns a single number from one to ten to represent the total energy released by a quake. It is a logarithmic scale with a base of ten, meaning that an increase of one unit represents ten times more energy released. For example, a magnitude 7.0 quake releases ten times more energy than one measuring 6.0.

The amount of energy released in a quake, as measured by the Richter scale, closely correlates with the amount of its destructive potential. For this reason, it is the most widely understood scale for measuring tremors. Closely related to the Richter scale is the moment magnitude scale. It is also logarithmic, but with a base of 30 rather than 10.

The moment magnitude scale measures energy release as a function of the rigidity of the earth, multiplied by the amount of displacement that takes place along a fault, as well as the size of the area which was displaced. Recently, the moment magnitude scale has begun to replace the Richter scale as the most commonly used of the two. In practice, the moment magnitude of a quake is often numerically similar to its Richter scale value, causing this switch to go mostly unnoticed.

4. 2.1.4 Earthquake Kit

When the earth rumbles and quakes, leaving buildings, homes, and belongings in a pile of rubble, having a tremor kit on hand is key to survival. Recovery from any catastrophe requires essential human needs be met, and in some cases, being tremor ready can mean the difference between life and death. As a general rule of thumb, kits should include supplies to maintain a family of four for at least three days. These supplies include:

Water: This is absolutely vital. Water should be stored in plastic containers and each person should have a minimum of one gallon per day. Don't forget about pets too!

Food: Non-perishable items that don't require cooking are best. Nuts, dried fruits, canned goods, packaged snack foods such as crackers or granola bars, and peanut butter will all work, and be sure to include a can opener, plastic utensils, paper plates, and bowls. If required, add formula and infant food, and again, if you are a pet owner, be sure to include enough pet food to sustain your animals for several days.

First Aid Kit: No earthquake kit should be without first aid. This should include bandages, non-prescription drugs such as pain relievers, syrup of ipecac, digestive aids, antiseptic, antibiotic ointment, burn ointment, eye wash solution, thermometers, scissors, tweezers, and latex gloves. Extras of prescription medications are also a must have.

Documents: Make photocopies of identification, social security cards, credit cards, health records, immunization records, insurance cards, insurance policies, contracts, deeds, wills, stocks and bonds, important phone numbers, passports, and account numbers. This is a simple task that will save a lot of headaches.

Tools and Supplies: Be sure to have a flashlight, batteries, utility knife, hammer, screwdriver, wrench, matches, tape, warm clothing, work gloves, signal flare, needle and thread, bleach, disinfectant, sleeping bags, plastic garbage bags, and a crowbar.

Personal Hygiene: An earthquake kit should also include personal hygiene items such as soap, toilet paper, toothbrushes, toothpaste, feminine hygiene products, washrag, and hand sanitizer.

Money: Emergency cash and change might be needed if the banks are closed.

Local Map: Mark key locations such as hospitals and police departments.

Radio: A battery-operated radio will provide vital news and information.

An earthquake kit should be stored in an airtight container and placed in an easily accessed area. Ensure all members of the household are familiar with the appropriate procedures to follow in the event of an tremor and that they know the location of the kit.

4. 2.1.5 Earth Pressure

Earth pressure refers to the natural movement of the earth's soil. The movements will often apply pressure on existing structures. It is sometimes referred to as lateral earth pressure, which is measured by the amount of tension that occurs against basement or retaining walls. There are three types of forces, including at rest, passive or active earth pressure.

There is the common saying that a house creaks due to the fact that it is "settling," which is a direct reference to earth pressure. Natural movements and changes in the soil cause the foundation to move. Most of these changes and movements are slight. Despite the fact that most cases are slight enough to go undetected, there are instances where the amount of pressure is strong enough to result in visible cracks, leaning, crumbling or even complete relocation.

The effects of earth pressure may take time to accumulate before they become visible. Since the earth's soil is stablely evolving and changing at different rates during certain periods of time, many years may pass before any effects are seen at all. Some types of soils or landscapes are more vulnerable to change, meaning that structures built in those areas are more likely to fail or sustain damage sooner.

There are a few theories that attempt to explain the type and amount of active earth pressure. One of those is the Rankine Theory. It assumes that the soil and horizontal structures do not experience pressure. Rather there is only pressure in vertical walls. Failures occur within a certain parameter and manifest as a wedge in the structure as a result of a force that is parallel to the wall.

Another theory, which is called the Coulomb Theory, states that there is active pressure between a structure and the earth's soil. The pressure does not just occur within vertical structures, but horizontal ones as well. Pressure forces and friction of the soil occur in other areas that are not parallel to the structure, according to the theory.

Both of these theories involve mathematical calculations that can be used to determine the amount of soil pressure. The calculations are used to predict both active and passive earth pressures. With passive pressure, the wall or structure moves towards the soil. In active cases, structures are pushed away from the soil. In contrast, at rest cases indicate no movement, either due to in important amounts of pressure or no changes in the earth's composition.

4. 2.2 Landslide

A landslide or land-slip is a geological phenomenon which includes a wide range of ground movements, such as rock falls, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments. Although the action of gravity is the primary driving force for a land-slip to occur, there are other contributing factors affecting the original slope stability. Typically, pre-conditional factors build up specific sub-surface conditions that make the area/slope prone to failure, whereas the actual land-slip often requires a trigger before being released.

4.2.2.1 Causes

The **causes of landslips** are usually related to instabilities in slopes. It is usually possible to identify one or more land-slip causes and one land-slip trigger. The difference between these two theories is subtle but important. The land-slip causes are the reasons that a land-slip occurred in that location and at that time. Land-slip causes are listed in the following table, and include geological factors, morphological factors, physical factors and factors associated with human activity.

Causes may be considered to be factors that made the slope vulnerable to failure, that predispose the slope to becoming unstable. The trigger is the single event that finally initiated the land-slip. Thus, causes combine to make a slope vulnerable to failure, and the trigger finally initiates the movement. Landslips can have many causes but can only have one trigger as shown in the next figure. Usually, it is relatively easy to determine the trigger after the land-slip has occurred (although it is generally very difficult to determine the exact nature of land-slip triggers ahead of a movement event).

Occasionally, even after detailed investigations, no trigger can be determined - this was the case in the large Mount Cook land-slip in New Zealand 1991. It is unclear as to whether the lack of a trigger in such cases is the result of some unknown procedure acting within the land-slip, or whether there was in fact a trigger, but it cannot be determined. Perhaps this is because the trigger was in fact a slow but steady decrease in material strength associated with the climatic of the rock - at some point the material becomes so weak that failure must occur. Hence the trigger is the climatic procedure, but this is not detectable externally. In most cases we think of a trigger as an external stimulus that induces an immediate or near-immediate response in the slope, in this case in the form of the movement of the land-slip. Generally this movement is induced either because the stresses in the slope are altered, perhaps by increasing shear stress or decreasing the effective normal stress, or by reducing the resistance to the movement perhaps by decreasing the shear strength of the materials within the land-slip.

4.2.2.2 Causes of landslides

4.2.2.2.1 Geological causes

- Climateed Materials e.g heavy rainfall
- Sheared materials
- Jointed or fissured materials
- Adversely orientated discontinuities
- Permeability contrasts
- Material contrasts
- Rainfall and snow fall

- Earthquakes
- Working of machinery

4.2.2.2.2 Morphological causes

- Slope angle
- Uplift
- Rebound
- Fluvial erosion
- Wave erosion
- Glacial erosion
- Erosion of lateral margins
- Subterranean erosion
- Slope loading
- Vegetation change
- Erosion

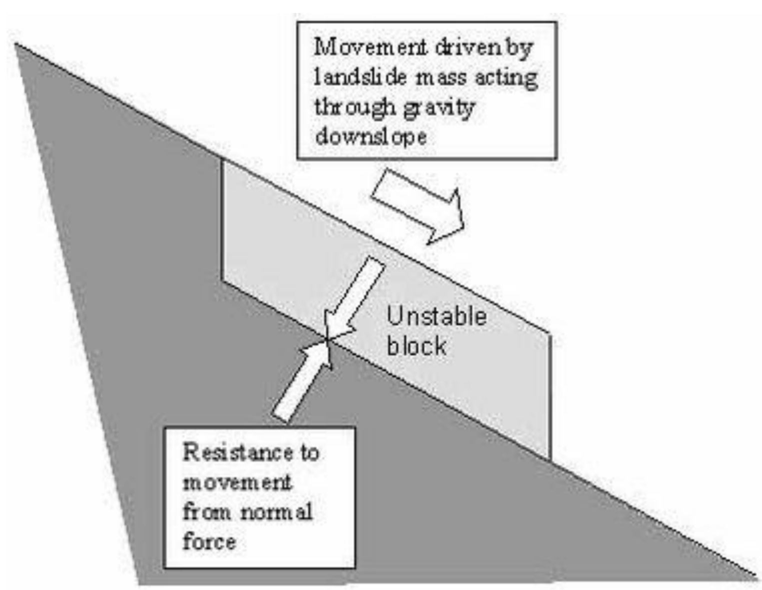
4.2.2.2.3 Physical causes

- Intense rainfall
- Rapid snow melt
- Prolonged precipitation
- Rapid drawdown
- Tremor
- Volcanic eruption
- Thawing
- Freeze-thaw
- Ground water changes
- Soil pore water pressure
- Surface runoff
- Seismic activity
- Soil erosion

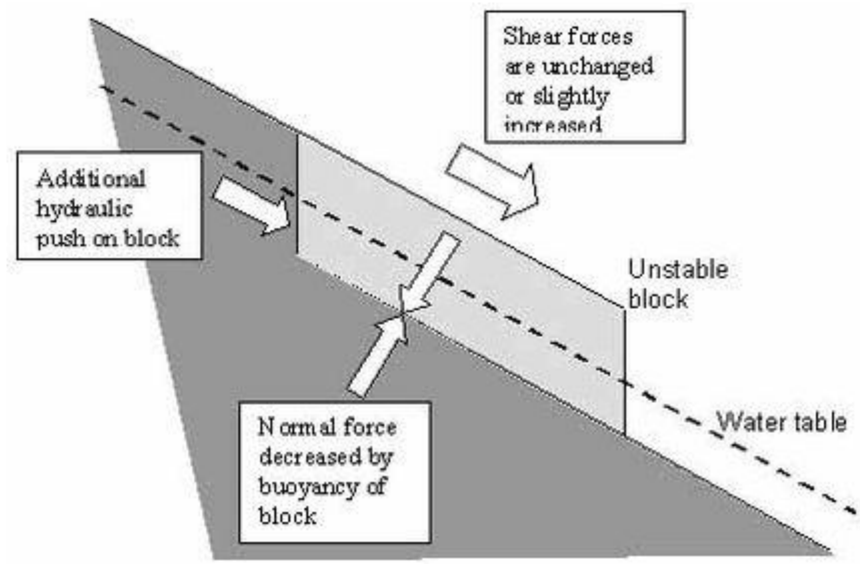
4.2.2.2.4 Human causes

- Excavation
- Loading
- Drawdown
- Land use change
- Water management
- Mining
- Quarrying
- Vibration
- Water leakage
- Deforestation
- Land use pattern
- Pollution

In the majority of cases the main trigger of landslips is heavy or prolonged rainfall. Generally this takes the form of either an exceptional short lived event, such as the passage of a tropical cyclone or even the rainfall associated with a particularly intense thunderstorm or of a long duration rainfall event with lower intensity, such as the cumulative effect of monsoon rainfall in South Asia. In the former case it is usually necessary to have very high rainfall intensities, whereas in the latter the intensity of rainfall may be only moderate - it is the duration and existing pore water pressure conditions that are important. The importance of rainfall as a trigger for landslips cannot be underestimated. A global survey of land-slip occurrence in the 12 months until the end of September 2003 revealed that there were 210 damaging land-slip events worldwide. Of these, over 90% were triggered by heavy rainfall. One rainfall event for example in Sri Lanka in May 2003 triggered hundreds of landslips, killing 266 people and rendering over 300,000 people temporarily homeless. In July 2003 an intense rain band associated with the annual Asian monsoon tracked across central Nepal, triggering 14 fatal landslips that killed 85 people. The reinsurance company Swiss Re estimated that rainfall induced landslips associated with the 1997-1998 El Nino event triggered landslips along the west coast of North, Central and South America that resulted in over $5 billion in losses. Finally, landslips triggered by Hurricane Mitch in 1998 killed an estimated 18,000 people in Honduras, Nicaragua, Guatemala and El Salvador. So why does rainfall trigger so many landslips? Principally this is because the rainfall drives an increase in pore water pressures within the soil. The Figure A illustrates the forces acting on an unstable block on a slope. Movement is driven by shear stress, which is generated by the mass of the block acting under gravity down the slope. Resistance to movement is the result of the normal load. When the slope fills with water, the fluid pressure provides the block with buoyancy, reducing the resistance to movement. In addition, in some cases fluid pressures can act down the slope as a result of groundwater flow to provide a hydraulic push to the land-slip that further decreases the stability. Whilst the example given in Figures A and B is clearly an artificial situation, the mechanics are essentially as per a real land-slip.



A: Diagram illustrating the resistance to, and causes of, movement in a slope system consisting of an unstable block



B: Diagram illustrating the resistance to, and causes of, movement in a slope system consisting of an unstable block

In some situations, the presence of high levels of fluid may destabilize the slope through other mechanisms, such as:

• Fluidization of debris from earlier events to form debris flows;

• Loss of suction forces in silty materials, leading to generally shallow failures (this may be an important mechanism in residual soils in tropical areas following deforestation);

• Undercutting of the toe of the slope through river erosion.

Considerable efforts have been made to understand the triggers for landsliding in natural systems, with quite variable results. For example, working in Puerto Rico, Larsen and Simon found that storms with a total precipitation of 100–200 mm, about 14 mm of rain per hour for several hours, or 2–3 mm of rain per hour for about 100 hours can trigger landslips in that environment. Rafi Ahmad, working in Jamaica, found that for the rainfall of short duration (about 1 hour) intensities of greater than 36 mm/h were required to trigger landslips. On the other hand, for long rainfall durations, low average intensities of about 3 mm/h appeared to be sufficient to cause landsliding as the storm duration approached approximately 100 hours. Corominas and Moya (1999) found that the following thresholds exist for the upper basin of the Llobregat River, Eastern Pyrenees area. Without antecedent rainfall, high intensity and short duration rains triggered debris flows and shallow slides developed in colluvium and acclimated rocks. A rainfall threshold of around 190 mm in 24 h initiated failures whereas more than 300 mm in 24-48 h was needed to cause widespread shallow landsliding. With antecedent rain, moderate intensity precipitation of at least 40 mm in 24 h reactivated mudslides and both rotational and translational slides affecting clayey and silty-clayey formations. In this case, several weeks and 200 mm of precipitation were needed to cause a land-slip reactivation. A similar approach is reported by Brand et al. (1988) for Hong Kong, who found that if the 24 hour antecedent rainfall exceeded 200 mm then the rainfall threshold for a large land-slip event was 70 mm hr-1. Finally, Caine (1980) established a worldwide threshold:

I = 14.82 D - 0.39 *where: I is the rainfall intensity (mm h-1), D is duration of rainfall (h)*

This threshold applies over time periods of 10 minutes to 10 days. It is possible to modify the formula to take into consideration areas with high mean annual precipitations by considering the proportion of mean annual precipitation represented by any individual event. Other techniques can be used to try to understand rainfall triggers, including:

• Actual rainfall techniques, in which measurements of rainfall are adjusted for potential evapotranspiration and then correlated with land-slip movement events

• Hydrogeological stable approaches, in which pore water pressure response to rainfall is used to understand the conditions under which failures are initiated

• Coupled rainfall - stability analysis methods, in which pore water pressure response models are coupled to slope stability models to try to understand the complexity of the system

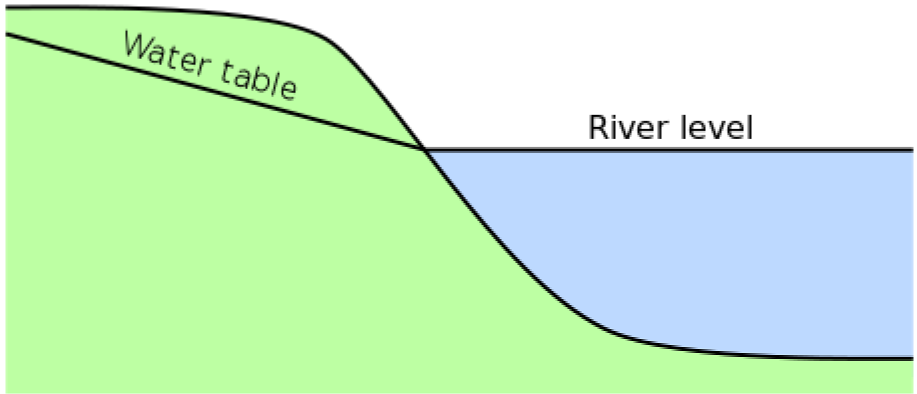
• Numerical slope modelling, in which finite element (or similar) models are used to try to understand the communications of all relevant procedures

4.2.2.2.5 Snowmelt

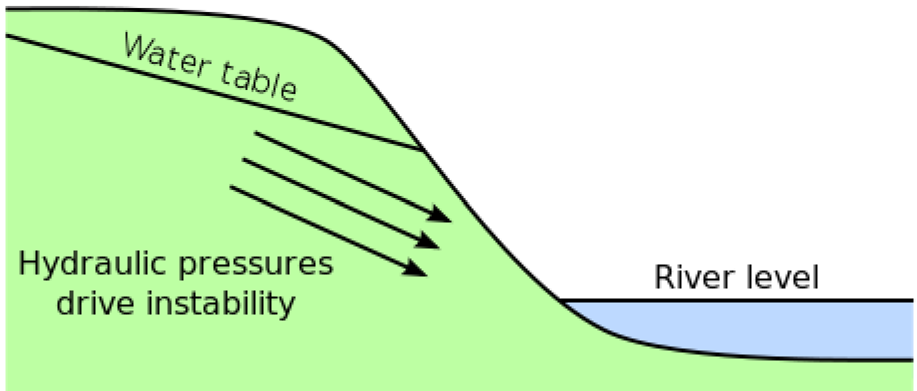
In many cold mountain areas, snowmelt can be a key mechanism by which land-slip initiation can occur. This can be especially important when sudden increases in temperature lead to rapid melting of the snow pack. This water can then infiltrate into the ground, which may have impermeable layers below the surface due to still-frozen soil or rock, leading to rapid increases in pore water pressure, and resultant land-slip activity. This effect can be especially serious when the warmer climate is accompanied by precipitation, which both adds to the groundwater and accelerates the rate of thawing.

4.2.2.2.6 Water-level change

Rapid changes in the groundwater level along a slope can also trigger landslips. This is often the case where a slope is adjacent to a water body or a river. When the water level adjacent to the slope falls rapidly the ground water level frequently cannot dissipate quickly enough, leaving an artificially high water table. This subjects the slope to higher than normal shear stresses, leading to potential instability. This is probably the most important mechanism by which river bank materials fail, being important after a flood as the river level is declining (i.e. on the falling limb of the hydrograph) as shown in the following figures.



Groundwater conditions when the river level is stable



Groundwater conditions on the falling limb of the hydrograph. If the fall in river levels is sufficiently rapid then the high water levels in the slope can provide a hydraulic push that destabilizes the slope, sometimes triggering bank collapse

It can also be important in coastal areas when sea level falls after a storm tide, or when the water level of a reservoir or even a natural lake rapidly falls. The most famous example of this is the Vajont failure, when a rapid decline in lake level contributed to the occurrence of a landslide that killed over 2000 people.

4.2.2.2.7 ***Rivers***

In some cases, failures are triggered as a result of undercutting of the slope by a river, especially during a flood. This undercutting serves both to increase the gradient of the slope, reducing stability, and to remove toe weighting, which also decreases stability. For example, in Nepal this procedure is often seen after a glacial lake outburst flood, when toe erosion occurs along the channel. Immediately after the passage of flood waves extensive landsliding often occurs. This instability can continue to occur for a long time afterwards, especially during subsequent periods of heavy rain and flood events.

4.2.2.2.8 Seismicity

The second major factor in the triggering of landslips is seismicity. Landslips occur during tremors as a result of two separate but interconnected procedures: seismic shaking and pore water pressure generation.

4.2.2.2.8.1 Seismic shaking

The passage of the tremor waves through the rock and soil produces a complex set of accelerations that effectively act to change the gravitational load on the slope. So, for example, vertical accelerations successively increase and decrease the normal load acting on the slope. Similarly, horizontal accelerations induce a shearing force due to the inertia of the land-slip mass during the accelerations. These procedures are complex, but can be sufficient to induce failure of the slope. These procedures can be much more serious in mountainous areas in which the seismic waves interact with the terrain to produce increases in the magnitude of the ground accelerations. This procedure is termed 'topographic amplification'. The maximum acceleration is usually seen on the crest of the slope or along the ridge line, meaning that it is a characteristic of seismically triggered landslips that they extend to the top of the slope.

4.2.2.2.9 Liquefaction

The passage of the tremor waves through a granular material such as a soil can induce a procedure termed liquefaction, in which the shaking causes a reduction in the pore space of the material. This densification drives up the pore pressure in the material. In some cases this can change a granular material into what is effectively a liquid, generating 'flow slides' that can be rapidly and thus very damaging. Alternatively, the increase in pore pressure can reduce the normal stress in the slope, allowing the activation of translational and rotational failures.

4.2.2.2.10 The nature of seismically-triggered landslips

For the main part seismically generated landslips usually do not differ in their morphology and internal procedures from those generated under non-seismic conditions. However, they tend to be more widespread and sudden. The most abundant types of tremor -induced landslips are rock falls and slides of rock fragments that form on steep slopes. However, almost every other type of land-slip is possible, including highly disaggregated and fast-moving falls; more coherent and slower-moving slumps, block slides, and earth slides; and lateral spreads and flows that involve partly to completely liquefy material (Keefer, 1999). Rock falls, disrupted rock slides, and disrupted slides of earth and debris are the most abundant types of tremor -induced landslips, whereas earth flows, debris flows, and avalanches of rock, earth, or debris typically transport material the farthest. There is one type of land-slip that is essentially uniquely limited to tremors - liquefaction failure, which can cause fissuring or subsidence of the ground. Liquefaction involves the temporary loss of strength of sands and silts which behave as viscous fluids rather than as soils. This can have devastating effects during large tremors.

4.2.2.2.11 Volcanic activity

Some of the largest and most destructive landslips known have been associated with volcanoes. These can occur either in association with the eruption of the volcano itself, or as a result of the mobilization of the very weak deposits that are formed as a consequence of volcanic activity. Essentially, there are two main types of volcanoes land-slip: lahars and debris avalanches, the largest of which are sometimes termed flank collapses. An example of a lahar was seen at Mount St Helens during its catastrophic eruption on May 18, 1980. Failures on volcanic flanks themselves are also common. For example, a part of the side of

Casita Volcano in Nicaragua collapsed on October 30, 1998 during the heavy precipitation associated with the passage of Hurricane Mitch. Debris from the initial small failure eroded older deposits from the volcano and incorporated additional water and wet sediment from along its path, increasing in volume about ninefold. The lahar killed more than 2,000 people as it swept over the towns of El Porvenir and Rolando Rodriguez at the base of the mountain. Debris avalanches commonly occur at the same time as an eruption, but occasionally they may be triggered by other factors such as a seismic shock or heavy rainfall. They are particularly common on strato volcanoes, which can be massively destructive due to their large size. The most famous debris avalanche occurred at Mount St Helens during the massive eruption in 1980. On May 18, 1980, at 8:32 a.m. local time, a magnitude 5.1 tremor shook Mount St. Helens. The bulge and surrounding area slid away in a gigantic rockslide and debris avalanche, releasing pressure, and triggering a major pumice and ash eruption of the volcano. The debris avalanche had a volume of about 1 km^3 (0.24 cu mi), traveled at 50 to 80 m/s (110 to 180 mph), and covered an area of 62 km^2 (24 sq mi), killing 57 people.

4.2.2.2.12 **Types**

4.2.2.2. 12.1 **Debris flow**

Slope material that becomes saturated with water may develop into a debris flow or mud flow. The resulting slurry of rock and mud may pick up trees, houses and cars, thus blocking bridges and tributaries causing flooding along its path.

Debris flow is often mistaken for flash flood, but they are entirely different procedure.

Muddy-debris flows in alpine areas cause severe damage to structures and infrastructure and often claim human lives. Muddy-debris flows can start as a result of slope-related factors and shallow landslips can dam stream beds, resulting in temporary water blockages. As the impoundments fail, a "domino effect" may be created, with a remarkable growth in the volume of the flowing mass, which takes up the debris in the stream channel. The solid-liquid mixture can reach densities of up to 2 tons/m^3 and velocities of up to 14 m/s (Chiarle and Luino, 1998; Arattano, 2003). These procedures normally cause the first severe road interruptions, due not only to deposits accumulated on the road (from several cubic meters to hundreds of cubic meters), but in some cases to the complete removal of bridges or roadways or railways crossing the stream channel. Damage usually derives from a common underestimation of mud-debris flows: in the alpine valleys, for example, bridges are frequently destroyed by the impact force of the flow because their span is usually calculated only for a water discharge. For a small basin in the Italian Alps (area = 1.76 km^2) affected by a debris flow, Chiarle and Luino (1998) estimated a peak discharge of 750 m^3/s for a section located in the middle stretch of the main channel. At the same cross section, the maximum foreseeable water discharge (by HEC-1), was 19 m^3/s, a value about 40 times lower than that calculated for the debris flow that occurred.

4.2.2.2. 12.2 **Earth flow**

Earthflows are downslope, viscous flows of saturated, fine-grained materials, which move at any speed from slow to fast. Typically, they can move at speeds from 0.17 to 20 km/h. Though these are a lot like mudflows, overall they are slower moving and are covered with solid material carried along by flow from within. They are different from fluid flows in that they are more rapid. Clay, fine sand and silt, and fine-grained, pyroclastic material are all susceptible to earthflows. The velocity of the earthflow is all dependent on how much water content is in the flow itself: if there is more water content in the flow, the higher the velocity will be.

These flows usually begin when the pore pressures in a fine-grained mass increase until enough of the weight of the material is supported by pore water to importantly decrease the internal shearing strength of the material. This thereby creates a bulging lobe which advances with a slow, rolling motion. As these lobes spread out, drainage of the mass increases and the margins dry out, thereby lowering the overall velocity of the flow. This procedure causes the flow to thicken. The bulbous variety of earthflows are not that spectacular, but they are much more common than their rapid counterparts. They develop a sag at their heads and are usually derived from the slumping at the source.

Earthflows occur much more during periods of high precipitation, which saturates the ground and adds water to the slope content. Fissures develop during the movement of clay-like material which creates the intrusion of water into the outflows. Water then increases the pore-water pressure and reduces the shearing strength of the material.

4.2.2.2. 12.3 Debris landslide

A debris slide is a type of slide characterized by the chaotic movement of rocks, soil and debris mixed with water or ice (or both). They are usually triggered by the saturation of thickly vegetated slopes which results in an incoherent mixture of broken timber, smaller vegetation and other debris. Debris avalanches differ from debris slides because their movement is much more rapid. This is usually a result of lower cohesion or higher water content and commonly steeper slopes.

Steep coastal cliffs can be caused by catastrophic debris avalanches. These have been common on the submerged flanks of ocean island volcanoes such as the Hawaiian Islands and the Cape Verde Islands. Another slip of this type was Storegga land-slip.

Movement: Debris slides generally start with big rocks that start at the top of the slide and begin to break apart as they slide towards the bottom. This is much slower than a debris avalanche. Debris avalanches are very fast and the entire mass seems to liquefy as it slides down the slope. This is caused by a combination of saturated material, and steep slopes. As the debris moves down the slope it generally follows stream channels leaving a V-shaped scar as it moves down the hill. This differs from the more U-shaped scar of a slump. Debris avalanches can also travel well past the foot of the slope due to their tremendous speed.

4.2.2. 12.4 Sturzstrom

A sturzstrom is a rare, poorly understood type of land-slip, typically with a long run-out. Often very large, these slides are unusually mobile, flowing very far over a low angle, flat, or even slightly uphill terrain.

4.2.2.2. 12.5 Shallow landslides

Landslide in which the sliding surface is located within the soil mantle or climateed bedrock (typically to a depth from few decimeters to some meters) is called a shallow land-slip. They usually include debris slides, debris flow, and failures of road cut-slopes. Landslips occurring as single large blocks of rock moving slowly down slope are sometimes called block glides.

Shallow landslips can often happen in areas that have slopes with high permeable soils on top of low permeable bottom soils. The low permeable, bottom soils trap the water in the shallower, high permeable soils creating high water pressure in the top soils. As the top soils are filled with water and become heavy, slopes can become very unstable and slide over the low permeable bottom soils. Say there is a slope with silt and sand as its top soil and bedrock as its bottom soil. During an intense rainstorm, the bedrock will keep the rain trapped in the top soils of silt and sand. As the topsoil becomes saturated and heavy, it can start to slide over the bedrock and become a shallow land-slip. R. H. Campbell did a study on shallow landslips on Santa Cruz Island California. He notes that if permeability decreases with depth, a perched water table may develop in soils at intense precipitation. When pore water pressures are sufficient to reduce effective normal stress to a critical level, failure occurs.

4.2.2.2. 12.6 Deep-seated landslides

Landslips in which the sliding surface is mostly deeply located below the maximum rooting depth of trees (typically to depths greater than ten meters). Deep-seated landslips usually involve deep regolith, climateed rock, and/or bedrock and include large slope failure associated with translational, rotational, or complex movement. These typically moves slowly, only several meters per year, but occasionally move faster. They tend to be larger than shallow landslips and form along a plane of weakness such as a fault or bedding plane. They can be visually identified by concave scarps at the top and steep areas at the toe.

4.2.2.2. 12.7 Causing tsunamis

Landslips that occur undersea, or have impact into the water, can generate tsunamis. Massive landslips can also generate megatsunamis, which are usually hundreds of meters high. In 1958, one such tsunami occurred in Lituya Bay in Alaska.

4.2.2.2. 12.8 Related phenomena

- An avalanche, similar in mechanism to a land-slip, involves a large amount of ice, snow and rock falling quickly down the side of a mountain.
- A pyroclastic flow is caused by a collapsing cloud of hot ash, gas and rocks from a volcanic explosion that moves rapidly down an erupting volcano.

4.2.2.2. 13 Landslide prediction mapping

Landslide risk analysis and mapping can provide useful information for catastrophic loss reduction, and assist in the development of guidelines for sustainable land use planning. The analysis is used to identify the factors that are related to landslips, estimate the relative contribution of factors causing slope failures, establish a relation between the factors and landslips, and to predict the land-slip risk in the future based on such a relationship. The factors that have been used for land-slip risk analysis can usually be grouped into geomorphology, geology, land use/land cover, and Hydrogeology. Since many factors are considered for land-slip risk mapping, GIS is an appropriate tool because it has functions of collection, storage, manipulation, display, and analysis of large amounts of spatially referenced data which can be handled fast and effectively. Remote sensing techniques are also highly employed for land-slip risk assessment and analysis. Before and after aerial photographs and satellite imagery are used to gather land-slip characteristics, like distribution and classification, and factors like slope, lithology, and land use/land cover to be used to help predict future events. Before and after imagery also helps to reveal how the landscape changed after an event, what may have triggered the land-slip, and shows the procedure of regeneration and recovery.

Using satellite imagery in combination with GIS and on-the-ground studies, it is possible to generate maps of likely occurrences of future landslips. Such maps should show the locations of previous events as well as clearly indicate the probable locations of future events. In general, to predict landslips, one must assume that their occurrence is determined by certain geologic factors, and that future landslips will occur under the same conditions as past events. Therefore, it is necessary to establish a relationship between the geomorphologic conditions in which the past events took place and the expected future conditions.

Natural calamities are a dramatic example of people living in conflict with the environment. Early predictions and warnings are essential for the reduction of property damage and loss of life. Because landslips occur frequently and can represent some of the most destructive forces on earth, it is imperative to have a good understanding as to what causes them and how people can either help prevent them from occurring or simply avoid them when they do occur. Sustainable land management and development is an essential key to reducing the negative impacts felt by landslips.

GIS offers a superior method for land-slip analysis because it allows one to capture, store, manipulate, analyze, and display large amounts of data quickly and effectively. Because so many variables are involved, it is important to be able to overlay the many layers of data to develop a full and accurate portrayal of what is taking place on the Earth's surface. Researchers need to know which variables are the most important factors that trigger landslips in any given location. Using GIS, extremely detailed maps can be generated to show past events and likely future events which have the potential to save lives, property, and money.

4.2.2.2. 14 Extraterrestrial landslides

Evidence of past landslips has been detected on many bodies in the solar system, but since most observations are made by probes that only observe for a limited time and most bodies in the solar system appear to be geologically inactive not many landslips are known to have happened in recent times. Both Venus and Mars have been subject to long-term mapping by orbiting satellites, and examples of landslides have been observed on both.

4.2.3 Tsunami

A **tsunami** is a series of water waves caused by the displacement of a large volume of a body of water, generally an ocean or a large lake. Tremors, volcanic eruptions and other underwater explosions (including detonations of underwater nuclear devices), landslips, glacier calving, meteorite impacts and other disturbances above or below the water all have the potential to generate a tsunami.

Tsunami waves do not resemble normal sea waves, because their wavelength is far longer. Rather than appearing as a breaking wave, a tsunami may instead initially resemble a rapidly rising tide, and for this reason they are often referred to as *tidal waves*. Tsunamis generally consist of a series of waves with periods ranging from minutes to hours, arriving in a so-called "wave train". Wave heights of tens of meters can be generated by large events. Although the impact of tsunamis is limited to coastal areas, their destructive power can be enormous and they can affect entire ocean basins; the 2004 Indian Ocean tsunami was among the deadliest natural calamities in human history with over 230,000 people killed in 14 countries bordering the Indian Ocean.

The Greek historian Thucydides suggested in his late 5th century BC, *History of the Peloponnesian War*, that the tsunamis were related to submarine tremor, but the understanding of a tsunami's nature remained slim until the 20th century and much remains unknown. Major areas of current research include trying to determine why some large tremors do not generate tsunamis while other smaller ones do; trying to accurately forecast the passage of tsunamis across the oceans; and also to forecast how tsunami waves would interact with specific shorelines.

A tsunami is sometimes referred to as **tidal waves**, which are unusually high sea waves that are triggered especially by tremors. In recent years, this term has fallen out of favor, especially in the systematic community, because tsunami actually has nothing to do with tides. The once-popular term derives from their most common appearance, which is that of an extraordinarily high tidal bore. Tsunami and tides both produce waves of water that move inland, but in the case of tsunami the inland movement of water is much greater and lasts for a longer period, giving the impression of an incredibly high tide. Although the meanings of "tidal" include "resembling" or "having the form or character of" the tides, and the term *tsunami* is no more accurate because tsunami is not limited to harbors, use of the term *tidal wave* is discouraged by geologists and oceanographers.

There are only a few other languages that have an equivalent native word. In Acehnese language, the words are *ië beuna* or *alôn buluëk* (depending on the dialect). In Tamil language, it is *aazhi peralai*. On Simeulue island, off the western coast of Sumatra in Indonesia, in Devayan language the word is *smong*, while in Sigulai language it is *emong*. In Singkil (in Aceh province) and surrounding, the people name tsunami with word *gloro*.

4.2.3.1 History

As early as 426 BC the Greek historian Thucydides inquired in his book *History of the Peloponnesian War* about the causes of tsunami, and was the first to argue that ocean tremors must be the cause.

"The cause, in my opinion, of this phenomenon must be sought in the tremor . At the point where its shock has been the most violent the sea is driven back, and suddenly recoiling with redoubled force, causes the inundation. Without an tremor I do not see how such an accident could happen."

The Roman historian Ammianus Marcellinus (*Res Gestae* 26.10.15-19) described the typical sequence of a tsunami, including an incipient tremor , the sudden retreat of the sea and a following gigantic wave, after the 365 AD tsunami devastated Alexandria.

While Japan may have the longest recorded history of tsunamis, the sheer destruction caused by the 2004 Indian Ocean tremor and tsunami event mark it as the most devastating of its kind in modern times, killing around 230,000 people. The Sumatran region is not unused to tsunamis either, with tremors of varying magnitudes regularly occurring off the coast of the island.

4.2.3.2 Generation mechanisms

The principal generation mechanism (or cause) of a tsunami is the displacement of a substantial volume of water or perturbation of the sea. This displacement of water is usually attributed to either tremors, landslides, volcanic eruptions, glacier calving's or more rarely by meteorites and nuclear tests. The waves formed in this way are then sustained by gravity. The tides do not play any part in the generation of tsunamis.

4.2.3.3 Seismicity

Tsunami can be generated when the sea floor abruptly deforms and vertically displaces the overlying water. Tectonic tremors are a particular kind of tremor that are associated with the Earth's crustal deformation; when these tremors occur beneath the sea, the water above the deformed area is displaced from its equilibrium position. More specifically, a tsunami can be generated when thrust faults associated with convergent or destructive plate boundaries move abruptly, resulting in water displacement, owing to the vertical component of movement involved. Movement on normal faults will also cause displacement of the seabed, but the size of the largest of such events is normally too small to give rise to an important tsunami.

Tsunamis have a small amplitude (wave height) offshore, and a very long wavelength (often hundreds of kilometers long, whereas normal ocean waves have a wavelength of only 30 or 40 meters), which is why they generally pass unnoticed at sea, forming only a slight swell usually about 300 millimeters (12 in) above the normal sea surface. They grow in height when they reach shallower water, in a wave shoaling procedure described below. A tsunami can occur in any tidal state and even at low tide can still inundate coastal areas.

On April 1, 1946, a magnitude-7.8 (Richter Scale) tremor occurred near the Aleutian Islands, Alaska. It generated a tsunami which inundated Hilo on the island of Hawai'i with a 14-meter high (46 ft) surge. The area where the tremor occurred is where the Pacific Ocean floor is subducting (or being pushed downwards) under Alaska.

Examples of tsunami originating at locations away from convergent boundaries include Storegga about 8,000 years ago, Grand Banks 1929, Papua New Guinea 1998 (Tappin, 2001). The Grand Banks and Papua New Guinea tsunamis came from tremors which destabilized sediments, causing them to flow into the ocean and generate a tsunami. They dissipated before traveling transoceanic distances.

The cause of the Storegga sediment failure is unknown. Possibilities include an overloading of the sediments, a tremor or a release of gas hydrates (methane etc.)

The 1960 Valdivia tremor (*MW* 9.5) (19:11 hrs UTC), 1964 Alaska tremor (*MW* 9.2), 2004 Indian Ocean tremor (*MW* 9.2) (00:58:53 UTC) and 2011 Tōhoku tremor (M_w9.0) are recent examples of powerful megathrust tremors that generated tsunamis (known as teletsunamis) that can cross entire oceans. Smaller (*MW* 4.2) tremors in Japan can trigger tsunamis (called **local** and **regional tsunamis**) that can only devastate nearby coasts, but can do so in only a few minutes.

4.2.3.4 Landslides

In the 1950s, it was discovered that larger tsunamis than had previously been believed possible could be caused by giant submarine landslips. These rapidly displace large water volumes, as energy transfers to the water at a rate faster than the water can absorb. Their existence was confirmed in 1958, when a giant land-slip in Lituya Bay, Alaska, caused the highest wave ever recorded, which had a height of 524 meters (over 1700 feet). The wave didn't travel far, as it struck land almost immediately. Two people fishing in the bay was killed, but another boat amazingly managed to ride the wave. Scientists named these waves megatsunami.

Scientists discovered that extremely large landslips from the volcanic island collapses can generate megatsunamis that can cross oceans.

4.2.3.5 Meteotsunamis

Some meteorological conditions, such as deep depressions that cause tropical cyclones, can generate a storm surge, called a meteotsunami, which can raise tides several meters above normal levels. The displacement comes from low atmospheric pressure within the center of the depression. As these storm surges reach shore, they may resemble (though are not) tsunamis, inundating vast areas of land.

4.2.3.6 Characteristics

Tsunamis cause damage by two mechanisms: the smashing force of a wall of water travelling at high speed, and the destructive power of a large volume of water draining off the land and carrying a large amount of debris with it, even with waves that do not look large.

While everyday wind waves have a wavelength (from crest to crest) of about 100 meters (330 ft) and a height of roughly 2 meters (6.6 ft), a tsunami in the deep ocean has a much larger wavelength of up to 200 kilometers (120 mi). Such a wave travels as well over 800 kilometers per hour (500 mph), but owing to the enormous wavelength the wave oscillation at any given point takes 20 or 30 minutes to complete a cycle and has an amplitude of only about 1 meter (3.3 ft). This makes tsunamis difficult to detect over deep water, where ships are unable to feel their passage.

The reason for the Japanese name "harbor wave" is that sometimes a village fisherman would sail out, and encounter no unusual waves while out at sea fishing, and come back to land to find their village devastated by a huge wave.

As the tsunami approaches the coast and the waters become shallow, wave shoaling compresses the wave and its speed decreases below 80 kilometers per hour (50 mph). Its wavelength diminishes to less than 20 kilometers (12 mi) and its amplitude grows enormously. Since the wave still has the same very long period, the tsunami may take minutes to reach full height. Except for the very largest tsunamis, the approaching wave does not break, but rather appears like a fast-moving tidal bore. Open bays and coastlines adjacent to very deep water may shape the tsunami further into a step-like wave with a steep-breaking front.

When the tsunami's wave peak reaches the shore, the resulting temporary rise in sea level is termed *run up*. Run up is measured in meters above a reference sea level. A large tsunami may feature multiple waves arriving over a period of hours, with important time between the wave crests. The first wave to reach the shore may not have the highest run up.

About 80% of tsunamis occur in the Pacific Ocean, but they are possible wherever there are large bodies of water, including lakes. They are caused by tremors, landslips, volcanic explosions, glacier calving, and bolides.

4.2.3.7 Drawback

All waves have a positive and negative peak, i.e. a ridge and a trough. In the case of a propagating wave like a tsunami, either may be the first to arrive. If the first part to arrive at the shore is the ridge, a massive breaking wave or sudden flooding will be the first effect noticed on land. However if the first part to arrive is a trough, a **drawback** will occur as the shoreline recedes dramatically, exposing normally submerged areas. Drawback can exceed hundreds of meters, and people unaware of the danger sometimes remain near the shore to satisfy their curiosity or to collect fish from the exposed seabed.

A typical wave period for a damaging tsunami is about 12 minutes. This means that if the drawback phase is the first part of the wave to arrive, the sea will recede, with areas well below sea level exposed after 3 minutes. During the next 6 minutes the tsunami wave trough builds into a ridge, and during this time the sea is filled in and destruction occurs on land. During the next 6 minutes, the tsunami wave changes from a ridge to a trough, causing flood waters to drain and drawback to occur again. This may sweep victims and debris some distance from land. The procedure repeats as the next wave arrives.

4.2.3.8 Scales of intensity and magnitude

As with tremors, several attempts have been made to set up scales of tsunami intensity or magnitude to allow comparison between different events.

4.2.3.9 Intensity scales

The first scales used routinely to measure the intensity of the tsunami were the *Sieberg-Ambraseys scale*, used in the Mediterranean Sea and the *Imamura-Iida intensity scale*, used in the Pacific Ocean. The latter scale was modified by Soloviev, who calculated the Tsunami intensity *I* according to the formula

$$I = \frac{1}{2} + \log_2 H_{av}$$

where H_{av} is the average wave height along the nearest coast. This scale, known as the *Soloviev-Imamura tsunami intensity scale*, is used in the global tsunami catalogues compiled by the NGDC/NOAA and the Novosibirsk Tsunami Laboratory as the main parameter for the size of the tsunami.

4.2.3.10 Magnitude scales

The first scale that genuinely calculated a magnitude for a tsunami, rather than an intensity at a particular location was the ML scale proposed by Murty & Loomis based on the potential energy. Difficulties in calculating the potential energy of the tsunami mean that this scale is rarely used. Abe introduced the *tsunami magnitude scale* M_t, calculated from,

$$M_t = a \log h + b \log R = D$$

Where *h* is the maximum tsunami-wave amplitude (in m) measured by a tide gauge at a distance *R* from the epicenter, *a*, *b* & *D* are stables used to make the M_t scale match as closely as possible with the moment magnitude scale.

4.2.3.11 Warnings and predictions

Drawbacks can serve as a brief warning. People who observe drawback (many survivors report an accompanying sucking sound), can survive only if they immediately run to high ground or seek the upper floors of nearby buildings. In 2004, ten-year old Tilly Smith of Surrey, England, was on Maikhao beach in Phuket, Thailand with her parents and sister, and having learned about tsunamis recently in school, told her family that a tsunami might be imminent. Her parents warned others minutes before the wave arrived, saving dozens of lives. She credited her geography teacher, Andrew Kearney.

In the 2004 Indian Ocean tsunami drawback was not reported on the African coast or any other east-facing coasts that it reached. This was because the wave moved downwards to the eastern side of the fault line and upwards on the western side. The western pulse hit coastal Africa and other western areas.

A tsunami cannot be precisely predicted, even if the magnitude and location of a tremor is known. Geologists, oceanographers, and seismologists analyze each tremor and based on many factors may or may not issue a tsunami warning. However, there are some warning signs of an impending tsunami, and automated systems can provide warnings immediate after a tremor in time to save lives. One of the most successful systems uses bottom pressure sensors, attached to buoys, which stablely monitor the pressure of the overlying water column.

Regions with a high tsunami risk typically use tsunami warning systems to warn the population before the wave reaches land. On the west coast of the United States, which is prone to Pacific Ocean tsunami, warning signs indicate evacuation routes. In Japan, the community is well-educated about tremors and tsunamis, and along the Japanese shorelines the tsunami warning signs are reminders of the natural risks together with a network of warning sirens, typically at the top of the cliff of surrounding hills.

The Pacific Tsunami Warning System is based in Honolulu, Hawai. It monitors Pacific Ocean seismic activity. A sufficiently large tremor magnitude and other information triggers a tsunami warning. While the subduction zones around the Pacific are seismically active, not all tremors generate tsunami. Computers assist in analyzing the tsunami risk of every tremor that occurs in the Pacific Ocean and the adjoining land masses.

As a direct result of the Indian Ocean tsunami, a re-appraisal of the tsunami threat for all coastal areas is being undertaken by national governments and the United Nations Disaster Mitigation Committee. A tsunami warning system is being installed in the Indian Ocean.

Computer models can predict tsunami arrival, usually within minutes of the arrival time. Bottom pressure sensors relay information in real time. Based on these pressure readings and other seismic information and the sea floor's shape (bathymetry) and coastal topography, the models estimate the amplitude and surge height of the approaching tsunami. All Pacific Rim countries collaborate in the Tsunami Warning System and most regularly practice evacuation and other procedures. In Japan, such preparation is mandatory for government, local authorities, emergency services and the population.

Some zoologists hypothesis that some animal species have an ability to sense subsonic Rayleigh waves from a tremor or a tsunami. If correct, monitoring their behavior could provide advance warning of tremors, tsunami etc. However, the evidence is controversial and is not widely accepted. There are unsubstantiated claims about the Lisbon quake that some animals escaped to higher ground, while many other animals in the same areas drowned. The phenomenon was also noted by media sources in Sri Lanka in the 2004 Indian Ocean tremor . It is possible that certain animals (e.g., elephants) may have heard the sounds of the tsunami as it approached the coast. The elephants' reaction was to move away from the approaching noise. By contrast, some humans went to the shore to investigate and many drowned as a result.

Along the United States west coast, in addition to the sirens, warnings are sent to television & radio via the National Climate Service, using the Emergency Alert System.

4.2.3.12 Forecast of tsunami attack probability

Kunihiko Shimazaki (University of Tokyo), a member of the Tremor Research Committee of The Headquarters for Tremor Research Promotion of Japanese government, mentioned the plan to public announcement of tsunami attack probability forecast at Japan National Press Club on 12 May 2011. The forecast includes tsunami height, attack area and occurrence probability within 100 years ahead. The forecast would integrate the systematic knowledge of recent interdisciplinary and the aftermath of the 2011 Tōhoku tremor and tsunami. As the plan, an announcement will be available from 2014.

4.2.3.13 Mitigation

In some tsunami-prone countries' tremor engineering measures have been taken to reduce the damage caused on shore.

Japan, where tsunami science and response measures first began following a disaster in 1896, has produced evermore elaborate countermeasures and response plans. That country has built many tsunami walls of up to 12 meters (39 ft) high to protect populated coastal areas. Other localities have built floodgates of up to 15.5 meters (51 ft) high and channels to redirect the water from incoming tsunami.

However, their effectiveness has been questioned, as tsunami often overstep the barriers. For example, the Okushiri, Hokkaidō tsunami which struck Okushiri Island of Hokkaidō within two to five minutes of the tremor on July 12, 1993 created waves as much as 30 meters (100 ft) tall—as high as a 10-story building. The port town of Aonae was completely surrounded by a tsunami wall, but the waves washed right over the wall and destroyed all the wood-framed structures in the area. The wall may have succeeded in slowing down and moderating the height of the tsunami, but it did not prevent major destruction and loss of life. Iwate Prefecture, which is an area at high risk from tsunami, had tsunami barrier walls totalling 25 kilometers (16 mi) long at coastal towns. The 2011 tsunami toppled more than 50% of the walls and caused many damages.

4.2.4 Anthropogenic hazard

Anthropogenic hazards can result in the form of a **human-made disaster**. In this case, *anthropogenic* means threats having an element of human intent, negligence, or error; or involving a failure of a human-made system. It results in a huge loss of life and property. It further affects a person's mental, physical and social well-being. This is opposed to natural disasters resulting from natural risks.

4.2.4.1 Technological hazards

4.2.4.1.1 Industrial hazards

Industrial disasters occur in a commercial context, such as mining accidents. They often have an ecological impact. The Bhopal disaster is the world's worst industrial calamity to date, and the Chernobyl calamity is regarded the worst nuclear accident in history. Risks may have longer-term and more dispersed effects, such as dioxin and DDT poisoning.

4.2.4.1.2 Structural collapse

Structural collapses are often caused by engineering failures. Bridge failures may be caused in several ways, such as under-design (as in the Tay Bridge disaster), by corrosion attack (such as in the Silver Bridge collapse), or by aerodynamic flutter of the deck (as in *Galloping Gertie*, the original Tacoma Narrows Bridge). Failure of dams was not infrequent during the Victorian era, such as the Dale Dyke dam failure in Sheffield, England in the 1860s, causing the Great Sheffield Flood. Other failures include balcony collapses or building collapses such as that of the World Trade Center.

4.2.4.1.3 Power outage

A power outage is an interruption of normal sources of electrical power. Short-term power outages (up to a few hours) are common and have minor adverse effect, since most businesses and health facilities are prepared to deal with them. Extended power outages, however, can disrupt personal and business activities as well as medical and rescue services, leading to business losses and medical emergencies. An extended loss of power can lead to civil disorder, as in the New York City blackout of 1977. Only very rarely do power outages escalate to calamity proportions, however, they often accompany other types of calamities, such as hurricanes and floods, which hampers relief efforts.

Electromagnetic pulses and voltage spikes from whatever cause can also damage electricity infrastructure and electrical devices.

Recent notable power outages include the 2005 Java–Bali Blackout which affected 100 million people, 2012 India blackouts which affected 600 million and the 2009 Brazil and Paraguay blackout which affected 60 million people.

4.2.4.1.4 Fire

Bush fires, forest fires, and mine fires are generally started by lightning, but also by human negligence or arson. They can burn thousands of square kilometers. If a fire intensifies enough to produce its own winds and "climate", it will form into a firestorm. A good example of a mine fire is the one near Centralia, Pennsylvania. Started in 1962, it ruined the town and continues to burn today. Some of the biggest city-related fires are The Great Chicago Fire, The Peshtigo Fire (both of 1871) and the Great Fire of London in 1666.

The casualties resulting from fires, regardless of their source or initial cause, can be aggravated by inadequate emergency preparedness. Such risks as a lack of accessible emergency exits, poorly marked escape routes, or improperly maintained fire extinguishers or sprinkler systems may result in many more deaths and injuries than might occur with such protections.

4.2.4.2 Hazardous materials

4.2.4.2.1 Radiation contamination

When nuclear weapons are detonated or nuclear containment systems are otherwise compromised, airborne radioactive particles (nuclear fallout) can scatter and irradiate large areas. Not only is it deadly, but it also has a long-term effect on the next generation for those who are contaminated. Ionizing radiation is hazardous to living things, and in such a case much of the affected area could be unsafe for human habitation. During World War II, United States troops dropped atomic bombs on the Japanese cities of Hiroshima and Nagasaki. As a result, the radiation fallout contaminated the cities' water supplies, food sources, and half of the population of each city were stricken with disease. In the Soviet Union, the Mayak industrial complex (otherwise known as Chelyabinsk-40 or Chelyabinsk-65) exploded in 1957. The Kyshtym calamity was kept secret for several decades. It is the third most serious nuclear accident ever recorded. At least 22 villages were exposed to radiation and resulted in at least 10,000 displaced persons. In 1992 the former soviet union officially acknowledge the accident. Other Soviet republics of Ukraine and Belarus suffered also when a reactor at the Chernobyl nuclear power plant had a meltdown in 1986. To this day, several small towns and the city of Chernobyl remain abandoned and uninhabitable due to fallout.

Another nuclear power calamity that is ongoing is Fukushima Daiichi.

In the 1970s, a similar threat scared millions of Americans when a failure occurred at the Three Mile Island Nuclear Power Plant in Pennsylvania. However, the incident was resolved and the area fortunately retained little contamination.

The Hanford Site is a decommissioned nuclear production complex that produced plutonium for most of the 60,000 weapons in the U.S. nuclear arsenal. There are ecological concerns about radioactivity released from Hanford.

Two major plutonium fires in 1957 and 1969 at the Rocky Flats Plant, located about 15 miles northwest of Denver was not publicly reported until the 1970s.

A number of military accidents involving nuclear weapons have also resulted in radioactive contamination, for example the 1966 Palomares B-52 crash and the 1968 Thule Air Base B-52 crash.

4.2.4.2.2 ***CBRNs***

CBRN is a catchall initialism for chemical, biological, radiological, and nuclear. The term is used to describe a non-conventional terror threat that, if used by a nation, would be considered use of a weapon of mass destruction. This term is used primarily in the United Kingdom. Planning for the possibility of a CBRN event may be appropriate for certain high-risk or high-value facilities and governments. Examples include Saddam Hussein's Halabja poison gas attack, the Sarin gas attack on the Tokyo subway and the preceding test runs in Matsumoto, Japan 100 kilometers outside of Tokyo, and Lord Amherst giving smallpox laden blankets to Native Americans.

4.2.4.3 **Transportation**

4.2.4.3.1 ***Aviation***

An aviation incident is an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations, passengers, or pilots. The category of the vehicle can range from a helicopter, an airliner, or a space shuttle. The world's worst airliner calamity is the Tenerife crash of 1977, when miscommunications between and amongst air traffic control and an aircrew caused two fully laden jets to collide on the runway, killing 583 people.

4.2.4.3.2 ***Rail***

A railroad calamity is an occurrence associated with the operation of a passenger train which results in substantial loss of life. Usually accidents with freight (goods) trains are not considered calamities, unless they cause substantial loss of life or property. One of the most devastating rail calamity occurred in 2004 in Sri Lanka when 1,700 people died in the Sri Lanka tsunami-rail calamity. Other notable rail disasters are the 1989 Ufa accident in Russia which killed 574, and the 1917 Modane train accident in France which killed 540.

4.2.4.3.3 ***Road***

Traffic collisions are the leading cause of death, and road-based pollution creates a substantial health risk, especially in major conurbations.

4.2.4.3.4 ***Space***

Space travel presents important risks, mostly to the direct participants (astronauts or cosmonauts and ground support personnel), but also carries the potential of calamity to the public at large. Accidents related to space travel have killed 22 astronauts and cosmonauts, and a larger number of people on the ground.

Accidents can occur on the ground during launch, preparation, or in flight, due to equipment malfunction or the naturally hostile environment of space itself. An additional risk is posed by (unmanned) low-orbiting satellites whose orbits eventually decay due to friction with the extremely thin atmosphere. If they are large enough, massive pieces travelling at great speed can fall to the Earth before burning up, with the potential to do damage.

The worst space disaster to date occurred on February 15, 1996 in Sichuan, China, when a Long March 3B rocket, carrying the Intelsat 708 telecommunications satellite, suffered a guidance system failure two seconds after liftoff and crashed into a nearby village. The Chinese government officially reported six deaths and 57 injuries, but some U.S. estimates run as high as 200 deaths.

The second worst disaster was the Nedelin catastrophe which occurred in the Soviet Union on October 24, 1960, when an R-16 intercontinental ballistic missile exploded on the launch pad, killing around 120 (best estimate) military ground support personnel. The Soviet government refused to acknowledge the incident until 1989, then claiming only 78 deaths.

One of the worst manned space accidents involved the Space Shuttle *Challenger, which* disintegrated in 1986, claiming all seven lives on board. The shuttle disintegrated 73 seconds after taking off from the launch pad in Cape Canaveral, Florida.

Another example is the Space Shuttle *Columbia*, which disintegrated during a landing attempt over Texas in 2003, with a loss of all seven astronauts on board. The debris field extended from New Mexico to Mississippi.

4.2.4.3.5 ***Sea travel***

Ships can sink, capsize or crash in disasters. Perhaps the most infamous sinking was that of the Titanic which hit an iceberg and sank, resulting in one of the worst maritime disasters in history. Other notable incidents include the capsizing of the Costa Concordia, which killed at least 32 people; and is the largest passenger ship to sink, and the sinking of the MV Doña Paz, which claimed the lives of up to 4,375 people in the worst peacetime maritime disaster in history.

4.3 Desertification, Forest Fire, Soil degradation & Population Explosion.

4.3.1 Desertification

Desertification is the procedure which turns productive into non- productive desert as a result of poor land-management. Desertification occurs mainly in semi-arid areas (average annual rainfall less than 600 mm) bordering on the deserts. In the Sahel, (the semi-arid area south of the Sahara Desert), for example, the desert moved 100 km southward between 1950 and 1975.

4.3.1.1 What causes desertification?

Overgrazing is the major cause of desertification worldwide. Plants of semi-arid areas are adapted to being eaten by sparsely scattered, large, grazing mammals which move in response to the patchy rainfall common to these regions. Early human pastoralists living in semi-arid areas copied this natural system. They moved their small groups of domestic animals in response to food and water availability. Such regular stock movement prevented overgrazing of the fragile plant cover.

In modern times, the use of fences has prevented domestic and wild animals from moving in response to food availability, and overgrazing has often resulted. However, when used correctly, fencing is a valuable tool of good veld management.

The use of boreholes and windmills also allows livestock to stay all-year round in areas formerly grazed only during the rains when seasonal pans held water. Where not correctly planned and managed, provision of drinking water has contributed to the massive advance of deserts in recent years as animals gather around waterholes and overgraze the area.

* Cultivation of marginal lands, i.e. lands on which there is a high risk of crop failure and a very low economic return, for example, some parts of South Africa where maize is grown.

* Destruction of vegetation in arid regions, often for fuelwood.

* Poor grazing management after the accidental burning of semi-arid vegetation.

* Incorrect irrigation practices in arid areas can cause salinization, (the build up of salts in the soil) which can prevent plant growth.

When the practices described above coincide with drought, the rate of desertification increases dramatically.

Increasing human population and poverty contribute to desertification as poor people may be forced to overuse their environment in the short term, without the ability to plan for the long term effects of their actions. Where livestock has a social importance beyond food, people might be reluctant to reduce their stock numbers.

4.3.1.2 What are the effects of desertification?

Desertification reduces the ability of land to support life, affecting wild species, domestic animals, agricultural crops and people. The reduction in plant cover that accompanies desertification leads to accelerated soil erosion by wind and water. South Africa is losing approximately 300-400 million tonnes of topsoil every year. As vegetation cover and soil layer are reduced, raindrop impact and run-off increases.

Water is lost off the land instead of soaking into the soil to provide moisture for plants. Even long-lived plants that would normally survive droughts die. A reduction in plant cover also results in a reduction in the quantity of humus and plant nutrients in the soil, and plant production drops further. As the protective plant cover disappears, floods become more frequent and more severe. Desertification is self-reinforcing, i.e. once the procedure has started, conditions are set for continual deterioration.

4.3.1.3 How widespread is desertification?

About one third of the world's land surface is arid or semi-arid. It is predicted that global warming will increase the area of desert climates by 17% in the next century. The area at risk of desertification is thus large and likely to increase.

Worldwide, desertification is making approximately 12 million hectares useless for cultivation every year. This is equal to 10% of the total area of South Africa or 87% of the area of cultivated land in our country.

In the early 1980s it was estimated that, worldwide, 61% of the 3257 million hectares of all productive drylands (lands where stock are grazed and crops grown, without irrigation) were moderately to very severely decertified. The problem is clearly enormous.

4.3.1.4 Desertification in southern Africa

About half of southern Africa is semi-arid and thus at risk of desertification. The area already transformed into desert-like conditions is not accurately known because uncertainty surrounds the precise definition of a desert, and what the original state of the vegetation was in the semi-arid areas of southern Africa.

The areas which are known to deteriorate this century are mainly on the edges of the southern Kalahari. The deterioration of the Karoo is less well established. It is possible that desertification of the Karoo began in the last century, when sheep were first introduced, and before good records were available for the area.

In recent years the introduction of artificial water points into the Kalahari within Botswana, together with the widespread erection of veterinary fences, has led to the rapid desertification of huge areas. Similar schemes have the same effect in the southern Kalahari within South Africa and Bophuthatswana.

4.3.1.5 How can desertification be halted?

To halt desertification the number of animals on the land must be reduced, allowing plants to regrow. Soil conditions must be made favorable for plant growth by, for example, mulching. Mulch (a layer of straw, leaves or sawdust covering the soil) reduces evaporation, suppresses weed growth, enriches soil as it rots, and prevents runoff and hence erosion. Reseeding may be necessary in badly degraded areas. Mulching and reseeding are expensive practices.

However, the only realistic large-scale approach is to prevent desertification through good land management in semi-arid areas.

4.3.2 Forest fire

The most common risk in forests is forest fire. Wild fires are as old as the forests themselves. They pose a threat not only to the forest wealth but also to the entire regime to fauna and flora seriously disturbing the bio-variety and the ecology and environment of a region. During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twinges, which could burst into flames ignited by the slightest spark. The Himalayan forests, particularly, Garhwal Himalayas have been burning regularly during the last few summers, with colossal loss of vegetation cover of that region.
Forest fire causes unstable in nature and endangers biovariety by reducing the faunal and floral wealth. Traditional methods of fire prevention are not proving effective and it is now essential to raise public awareness on the matter, particularly among those people who live close to or in forested areas.

4.3.2.1 Causes of forest fire

Forest fires are caused by Natural causes as well as Man made causes

- Natural causes- Many forest fires start from natural causes such as lightning which set trees on fire. However, rain extinguishes such fires without causing much damage. High atmospheric temperatures and dryness (low humidity) offer favorable circumstance for a fire to start.
- Man made causes- Fire is caused when a source of fire like naked flame, cigarette or bidi, electric spark or any source of ignition comes into contact with inflammable material.

Traditionally Indian forests have been affected by fires. Themenace has been aggravated with rising human and cattle population and the consequent increase in demand for Forest products by individuals and communities. Causes of forest fires can be divided into two broad categories: *ecological* (which are beyond control) and *human related* (which are controllable).

Ecological causes are largely related to climatic conditions such as temperature, wind speed and direction, level of moisture in the soil and atmosphere and duration of dry spells. Other natural causes are the friction of bamboos swaying due to high wind velocity and rolling stones that result in sparks setting off fires in highly inflammable leaf litter on the forest floor.

Human related causesresult from human activity as well as methods of forest management. These can be intentional or unintentional, for example:

- Graziers and gatherers of various forest products starting small fires to obtain good grazing grass as well as to facilitate gathering of minor forest produce like flowers of *Madhuca indica* and leaves of *Diospyros melanoxylon*
- The centuries old practice of shifting cultivation (especially in the North-Eastern region of India and in parts of the States of Orissa and Andhra Pradesh).
- The use of fires of villagers to ward off wild animals
- Fires lit intentionally by people living around forests for recreation
- Fires started accidentally by careless visitors to forests who discard cigarette butts.

The causes of forest fire have been increasing rapidly. The problem has been accentuated by the growing human and cattle population. People enter forests ever more frequently
to graze cattle, collect firewood, timber and other minor forest produce. It has been estimated that 90% of forest fires in India are man-made

4.3.2.2 Classification of Forest Fire
Forest fire can broadly be classified into three categories;

- Natural or controlled forest fire.
- Forest fires caused by heat generated in the litter and other biomes in summer through carelessness of people (human neglect) and
- Forest fires purposely caused by local inhabitants.

4.3.2.3 Types of Forest Fire

There are two types of forest fire i) Surface Fire and ii) Crown Fire

4.3.2.3.1 Surface Fire-

A forest fire may burn primarily as a surface fire, spreading along the ground as the surface litter (senescent leaves and twigs and dry grasses etc.) on the forest floor and is engulfed by the spreading flames.

4.3.2.3.2 Crown Fire-

The other type of forest fire is a crown fire in which the crown of trees and shrubs burn, often sustained by a surface fire. A crown fire is particularly very dangerous in a coniferous forest because the resinous material given off burning logs burn furiously. On hill slopes, if the fire starts downhill, it speeds up fast as heated air adjacent to a slope tends to flow up the slope spreading flames along with it. If the fire starts uphill, there is less likelihood of it spreading downwards.

4.3.2.4 Effect of forest fire

Fires are a major cause of forest degradation and have wide ranging adverse ecological, economic and social impacts, including:

- Loss of valuable timber resources
- Degradation of catchment areas
- Loss of biovariety and extinction of plants and animals
- Loss of wildlife habitat and depletion of wildlife
- Loss of natural regeneration and reduction in forest covers
- Global warming
- Loss of carbon sink resource and increase in percentage of CO_2 in atmosphere
- Change in the microclimate of the area with unhealthy living conditions
- Soil erosion affecting productivity of soils and production
- Ozone layer depletion
- Health problems leading to diseases
- Loss of livelihood for tribal people and the rural poor, as approximately 300 million people are directly dependent upon collection of non-timber forest products from forest areas for their livelihood.

4.3.2.5 The needs of the fire management

The incidence of forest fires in the country is on the increase and more area is burned each year. The major cause of this failure is the piecemeal approach to the problem. Both the national focus and the technical resources required for sustaining a systematic forest fire management program are lacking in the country. Important forest fire management elements like strategic fire centers, coordination between Ministries, funding, human resource development, fire research, fire management, and extension programs are missing.
Taking into consideration the serious nature of the problem, it is necessary to make some major improvements in the forest fire management strategy for the country. The Ministry of Environment and

Forests, Government of India, has prepared a National Master Plan for Forest Fire Control. This plan proposes to introduce a well-coordinated and integrated fire-management program that includes the following components:

- Prevention of human-caused fires through education and ecological modification. It will include silvicultural activities, engineering works, people participation, and education and enforcement. It is proposed that more emphasis be given to people participation through Joint Forest Fire Management for fire prevention.
- Prompt detection of fires through a well coordinated network of observation points, efficient ground patrolling, and communication networks. Remote sensing technology is to be given due importance in fire detection. For successful fire management and administration, a National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed in the country.
- Fast initial attack measures.
- Vigorous follow up action.
- Introducing a forest fuel modification system at strategic points.
- Firefighting resources.

Each of the above components plays an important role in the success of the entire system of fire management. Special emphasis is to be given to research, training, and development

Integrated forest protection

The main objective of this scheme to control forest fires and strengthen the forest protection in Tamilnadu. The works like Fireline clearing, assistance to Joint Forest Management committees, creating water bodies, purchase of vehicles and communication equipments, purchase of fire fighting tools, etc., are being undertaken.

4.3.3 Soil degradation

Soil retrogression and degradation are two regressive evolution procedures associated with the loss of equilibrium of a stable soil. Retrogression is primarily due to erosion and corresponds to a phenomenon where succession reverts to pioneer conditions (such as bare ground). Degradation is an evolution, different from natural evolution, related to the local climate and vegetation. It is due to the replacement of primary plant communities (known as climax) by the secondary communities. This replacement modifies the humus composition and amount, and affects the formation of the soil. It is directly related to human activity. **Soil degradation** may also be viewed as any change or disturbance to the soil perceived to be deleterious or undesirable.

At the beginning of soil formation, the bare rock out crops is gradually colonized by pioneer species (lichens and mosses). They are succeeded by herbaceous vegetation, shrubs and finally forest. In parallel, the first humus-bearing horizon is formed (the A horizon), followed by some mineral horizons (B horizons). Each successive stage is characterized by a certain association of soil/vegetation and environment, which defines an ecosystem.

After a certain time of parallel evolution between the ground and the vegetation, a state of steady stable is reached. This stage of development is called a climax by some ecologists and "natural potential" by others. Succession is the evolution towards climax. Regardless of its name, the equilibrium stage of primary succession is the highest natural form of development that the ecological factors are capable of producing.

The cycles of evolution of soils have very variable durations, between tens, hundreds, or thousands of years for quickly evolving soils (A horizon only) to more than a million years for slowly developing soils. The same soil may achieve several successive steady state conditions during its existence, as exhibited by the Pygmy forest sequence in Mendocino County, California. Soils naturally reach a state of high productivity, from which they naturally degrade as mineral nutrients are removed from the soil system. Thus older soils are more vulnerable to the effects of induced retrogression and degradation.

4.3.3.1 Ecological factors influencing soil formation

There are two types of ecological factors influencing the evolution of a soil (through alteration and humification). These two factors are extremely important to explain the evolution of soils of short development.

- A first type of factor is the average climate of an area and the vegetation which is associated (biome).
- A second type of factor is more local, and is related to the original rock and local drainage. This type of factor explains the appearance of specialized associations (ex peat bogs).

4.3.3.2 Biorhexistasy theory

The destruction of the vegetation implies the destruction of Evoluted soils, or a regressive evolution. Cycles of succession-regression of soils follow one another within short intervals of time (human actions) or long intervals of time (climate variations).

The climate role in the deterioration of the rocks and the formation of soils leads to the formulation of the theory of the biorhexistasy.

- In wet climates, the conditions are favorable to the deterioration of the rocks (mostly chemically), the development of the vegetation and the formation of soils; this period favorable to life is called biostasy.
- In a dry climate, the rocks exposed are mostly subjected to the mechanical disintegration which produces coarse detrital materials: this is referred to as rhexistasy.

4.3.3.3 Perturbations of the stability of a soil

When the state of stable, characterized by the ecosystem climax is reached, it tends to be maintained stable in the course of time. The vegetation installed on the ground provides the humus and ensures the ascending circulation of the matters. It protects the ground from erosion by playing the role of barrier (for example, protection from water and wind). Plants can also reduce erosion by binding the particles of the ground to their roots.

A disturbance of climax will cause retrogression, but often, secondary succession will start to guide the evolution of the system after that disturbance. Secondary succession is much faster than primary because the soil is already formed, although deteriorated and needing restoration as well.

However, when an important destruction of the vegetation takes place (of natural origin such as an avalanche or human origin), the disturbance undergone by the ecosystem is too important. In this latter case, erosion is responsible for the destruction of the upper horizons of the ground, and is at the origin of a phenomenon of reversion to pioneer conditions. The phenomenon is called retrogression and can be partial or total (in this case, nothing remains beside a bare rock). For example, the clearing of an inclined ground, subjected to violent rains, can lead to the complete destruction of the soil. Man can deeply modify the evolution of the soils by direct and brutal action, such as clearing, abusive cuts, forest pasture, litters raking. The climax vegetation is gradually replaced and the soil modified (example: replacement of leafy tree forests by moors or pines plantations). Retrogression is often related to very old human practices.

Influence of human activity

Erosion is the main factor for soil degradation and is due to several mechanisms: water erosion, wind erosion, chemical degradation and physical degradation.

Erosion is strongly related to human activity. For example, roads which increase impermeable surfaces lead to streaming and ground loss. Agriculture also accelerates soil erosion (increase of field size, correlated to hedges and ditches removal). Meadows are in regression to the profit of plowed lands. Spring cultures (sunflower, corn, beet) surfaces are increasing and leave the ground naked in the winter. Sloping grounds are gradually colonized by vine. Lastly, the use of herbicides leaves the ground naked between each crop. New cultural practices, such as mechanization also increase the risks of erosion. Fertilization by mineral manures rather than organic manure gradually destructure the soil. Many scientists observed a gradual decrease of soil organic matter content in soils, as well as a decrease of soil biological activity (in particular, in relation to chemical uses). Lastly, deforestation, in particular, is responsible for degradation of forest soils.

Agriculture increases the risk of erosion through its disturbance of vegetation by way of:

- Overgrazing of animals
- Monoculture planting
- Row cropping
- Tilling or plowing
- Crop removal
- Land-use conversion

4.3.3.4 Consequences of soil regression and degradation

- Yields impact: Recent increases in the human population have placed a great strain on the world's soil systems. More than 6 billion people are now using about 38% of the land area of the Earth to raise crops and livestock. Many soils suffer from various types of degradation, that can ultimately reduce their ability to produce food resources. Slight degradation refers to land where yield potential has been reduced by 10%, moderate degradation refers to a yield decrease from 10-50%. Severely degraded soils have lost more than 50% of their potential. Most severely degraded soils are located in developing countries.

- Natural disasters: natural disasters such as mud flows, floods are responsible for the death of many living beings each year.

- Deterioration of the water quality: the increase in the turbidity of water and the contribution of nitrogen and of phosphorus can result in eutrophication. Soil particles in surface waters are also accompanied by agricultural inputs and by some pollutants of industrial, urban and road origin (such as heavy metals). The ecological impact of agricultural inputs (such as weed killer) is known but difficult to evaluate because of the multiplicity of the products and their broad spectrum of action.

- Biological variety: soil degradation may involve the disappearance of the climax vegetation and decrease in animal habitat, thus leading to a biovariety loss and animal extinction.

4.3.3.5 Soil enhancement, rebuilding, and regeneration

Problems of soil erosion can be fought, and certain practices can lead to soil enhancement and rebuilding. Even though simple, methods for reducing erosion are often not chosen because these practices outweigh the short-term benefits. Rebuilding is especially possible through the improvement of soil structure, addition of organic matter and limitation of runoff. However, these techniques will never totally succeed to restore a soil (and the fauna and flora associated with it) that took more than 1000 years to build up. **Soil regeneration** is the reformation of degraded soil through biological, chemical, and or physical procedures.

When productivity declined in the low-clay soils of northern Thailand, farmers initially responded by adding organic matter from termite mounds, but this was unsustainable in the long-term. Scientists experimented with adding bentonite, one of the smectite family of clays, to the soil. In field trials, conducted by scientists from the International Water Management Institute in cooperation with Khon Kaen University and local farmers, this had the effect of helping retain water and nutrients. Supplementing the farmer's usual practice with a single application of 200 kg bentonite per Rai (6.26 Rai = 1 hectare) resulted in an average yield increase of 73%. More work showed that applying bentonite to degraded sandy soils reduced the risk of crop failure during drought years.

In 2008, three years after the initial trials, IWMI scientists conducted a survey among 250 farmers in northeast Thailand, half who had applying bentonite to their fields and half who had not. The average output for those using the clay addition was 18% higher than for non-clay users. Using the clay had enabled some farmers to switch to growing vegetables, which need more fertile soil. This helped to increase their income. The researchers estimated that 200 farmers in northeast Thailand and 400 in Cambodia had adopted the use of clays, and that a further 20,000 farmers were introduced to the new technique.

4.3.4 Population Explosion

Human overpopulation occurs if the number of people in a group exceeds the carrying capacity of the region occupied by the group. The term often refers to the relationship between the entire human population and its environment, the Earth, or to smaller geographical areas such as countries. Overpopulation can result from an increase in births, a decline in mortality rates, an increase in immigration, or an unsustainable biome and depletion of resources. It is possible for very sparsely populated areas to be overpopulated if the area has a meager or non-existent capability to sustain life (e.g. a desert).

The human population has been growing continuously since the end of the Black Death, around the year 1400, although the most important increase has been in the last 50 years, mainly due to medical advancements and increases in agricultural productivity. Although the rate of population growth has been declining since the 1980s, the United Nations has expressed concern about continued excessive population growth in sub-Saharan Africa. As of October 14, 2013 the world's human population is estimated to be 7.118 billion by the United States Census Bureau, and over 7 billion by the United Nations. Most contemporary estimates for the carrying capacity of the Earth under existing conditions are between 4 billion and 16 billion. Depending on which estimate is used, human overpopulation may or may not have already occurred. Nevertheless, the rapid recent increase in human population is causing some concern. The population is expected to reach between 8 and 10.5 billion between the year 2040 and

2050. In May 2011, the United Nations increased the medium variant projections to 9.3 billion for 2050 and 10.1 billion for 2100.

The recent rapid increase in human population over the past three centuries has raised concerns that the planet may not be able to sustain present or larger numbers of inhabitants. The InterAcademy Panel Statement on Population Growth, circa 1994, has stated that many ecological problems, such as rising levels of atmospheric carbon dioxide, global warming, and pollution, are aggravated by the population expansion. Other problems associated with overpopulation include the increased demand for resources such as fresh water and food, starvation and malnutrition, consumption of natural resources (such as fossil fuels) faster than the rate of regeneration, and a deterioration in living conditions. However, some believe that waste and over-consumption, especially by wealthy nations, is putting more strain on the environment than overpopulation.

Attempts to mitigate adverse effects associated with overpopulation have historically included eugenic efforts in the early 19th century. This focused on forcefully sterilizing people thought to have undesirable traits. Almost all developed countries developed laws and regulations around this theme of reducing the reproduction of undesirables. Besides sterilization, the methods included forced abortions, birth control, marriage restrictions according to race, limited genetic testing, racial segregation and segregation of the mentally disabled. The eugenics theory was expanded in Nazi Germany during WWII to forcibly exterminating anyone thought to be undesirable, most notably the Jews. Genocide is the procedure of reducing the population of a race or ethnic group by murder. Most countries have no direct policy of limiting their birth rates, but the rates have still fallen due to educating people about family planning, increasing access to birth control and contraception. Only China has imposed legal restrictions on having more than one child. Extraterrestrial settlement and other technical solutions have been proposed as ways to mitigate overpopulation in the future.

4.3.4.1 History of concern

Concern about overpopulation is ancient. Tertullian was a resident of the city of Carthage in the second century CE, when the population of the world was about 190 million (only three to four percent of what it is today). He notably said: "What most frequently meets our view (and occasions complaint) is our teeming population. Our numbers are burdensome to the world, which can hardly support us... In very deed, pestilence, and famine, and wars, and tremors have to be regarded as a remedy for nations, as the means of pruning the luxuriance of the human race." Before that, Plato, Aristotle and others broached the topic as well.

Throughout history, populations have grown slowly despite high birth rates, due to the population-reducing effects of war, plagues and high infant mortality. During the 750 years before the Industrial Revolution, the world's population increased very slowly, remaining under 250 million.

By the beginning of the 19th century, the world population had grown to a billion individuals, and intellectuals such as Thomas Malthus and physiocratic economists predicted that mankind would outgrow its available resources, since a finite amount of land was incapable of supporting an endlessly increasing population. Mercantillists argued that a large population was a form of wealth, which made it possible to create bigger markets and armies.

During the 19th century, Malthus's work was often interpreted in a way that blamed the poor alone for their condition, and helping them was regarded to worsen conditions in the long run. This resulted, for example, in the English poor laws in 1834 and in a hesitating response to the Irish Great Famine of 1845–52.

The UN Population Assessment Report of 2003 states that the world population will plateau by 2050 and will remain that way until 2300. Dr Alex Berezow states that overpopulation is not a Western world problem and people often cite China and India as major population contributors; however he notes that with rising wealth in those countries, population growth will begin to slow, as population growth is strongly linked to the economic stability of a country.

4.3.4.2 Human population

4.3.4.2.1 History of population growth

Population	
Year	**Billion**
1804	1
1927	2
1959	3
1974	4
1987	5
1999	6
2011	7
2020	7.7 (estimate)

The human population has gone through a number of periods of growth since the dawn of civilization in the Holocene period, around 10,000 BCE. The beginning of civilization roughly coincides with the receding of glacial ice following the end of the last glacial period. It is estimated that between 1-5 million people, subsisting on hunting and foraging, inhabited the Earth in the period before the neolithic revolution, when human activity shifted away from hunter-gathering and towards very primitive farming.

Around 8000 BCE, at the dawn of agriculture, the population of the world was approximately 5 million. The next several millennia saw a steady increase in the population, with a very rapid growth beginning in 1000 BCE, and a peak of between 200 and 300 million people in 1 BCE.

The Plague of Justinian caused Europe's population to drop by around 50% between 541 and the 8th century. Steady growth resumed in 800 CE. However, growth was again disrupted by frequent plagues; most notably, the Black Death during the 14th century. The effects of the Black Death are thought to have reduced the world's population, then at an estimated 450 million, to between 350 and 375 million by

1400. The population of Europe stood at over 70 million in 1340; these levels did not return until 200 years later. England's population reached an estimated 5.6 million in 1650, up from an estimated 2.6 million in 1500. New crops from the Americas via the Spanish colonizers in the 16th century contributed to the population growth.

In other parts of the globe, China's population at the founding of the Ming dynasty in 1368 stood close to 60 million, approaching 150 million by the end of the dynasty in 1644. The population of the Americas in 1500 may have been between 50 and 100 million.

Encounters between European explorers and populations in the rest of the world often introduced local epidemics of extraordinary virulence. Archaeological evidence indicates that the death of around 90% of the Native American population of the New World was caused by Old World diseases such as smallpox, measles, and influenza. Over the centuries, the Europeans had developed high degrees of immunity to these diseases, while the indigenous peoples had no such immunity.

After the start of the Industrial Revolution, during the 18th century, the rate of population growth began to increase. By the end of the century, the world's population was estimated at just under 1 billion. At the turn of the 20th century, the world's population was roughly 1.6 billion. By 1940, this figure had increased to 2.3 billion.

Population growth 1990–2009 (%)	
World	28.4%
Africa	58.4%
Middle East	53.4%
Asia (except China)	36.9%
Latin America	32.0%
OECD North America	25.1%
China	17.3%
OECD Europe	9.9%
OECD Pacific	9.5%
Non-OECD Europe and Eurasia	-2.7%

Dramatic growth beginning in 1950 (above 1.8% per year) coincided with greatly increased food production as a result of the industrialisation of agriculture brought about by the Green Revolution. The rate of human population growth peaked in 1964, at about 2.1% per year. For example, Indonesia's population grew from 97 million in 1961 to 237.6 million in 2010, a 145% increase in 49 years. In India, the population grew from 361.1 million people in 1951 to just over 1.2 billion by 2011, a 235% increase in 60 years.

Continent	1900 population
Africa	133 million
Asia	904 million
Europe	408 million
Latin America and Caribbean	74 million
North America	82 million

There is concern over the sharp population increase in many countries, especially in Sub-Saharan Africa, that has occurred over the last several decades, and that it is creating problems with land management, natural resources and access to water supplies.

The population of Chad has, for example, grown from 6,279,921 in 1993 to 10,329,208 in 2009. Vietnam, Mexico, Nigeria, Egypt, Ethiopia and the DRC are witnessing a similar growth in population. The situation is most acute in northern, western and central Africa. Refugees from places like Sudan have further strained the resources of neighboring states like Chad and Egypt. Chad is also host to roughly 255,000 refugees from Sudan's Darfur region, and about 77,000 refugees from the Central African Republic, while approximately 188,000 Chadians have been displaced by their own civil war and famines, have either fled to either the Sudan, the Niger or, more recently, Libya.

4.3.4.3 Projections of population growth

Continent	Projected 2050 population
Africa	1.8 billion
Asia	5.3 billion
Europe	628 million
Latin America and Caribbean	809 million
North America	392 million

According to projections, the world population will continue to grow until at least 2050, with the population reaching 9 billion in 2040, and some predictions putting the population in 2050 as high as 11 billion. Walter Greiling projected in the 1950s that world population would reach a peak of about nine billion, in the 21st century, and then stop growing, after a readjustment of the Third World and a sanitation of the tropics.

According to the United Nations' World Population Prospects report:

- The world population is currently growing by approximately 74 million people per year. Current United Nations predictions estimate that the world population will reach 9.0 billion around 2050, assuming a decrease in the average fertility rate from 2.5 down to 2.0.
- Almost all growth will take place in the less developed regions, where today's 5.3 billion population of underdeveloped countries is expected to increase to 7.8 billion in 2050. By contrast, the population of the more developed regions will remain mostly unchanged, at 1.2 billion. An exception is the United States population, which is expected to increase by 44% from 2008 to 2050.
- In 2000–2005, the average world fertility was 2.65 children per woman, about half the level in 1950–1955 (5 children per woman). In the medium variant, global fertility is projected to decline further to 2.05 children per woman.
- During 2005–2050, nine countries are expected to account for half of the world's projected population increase: India, Pakistan, Nigeria, Democratic Republic of the Congo, Bangladesh, Uganda, United States, Ethiopia, and China, listed according to the size of their contribution to population growth. China would be higher still in this list were it not for its one-child policy.
- Global life expectancy at birth is expected to continue rising from 65 years in 2000–2005 to 75 years in 2045–2050. In the more developed regions, the projection is for 82 years from 2050. Among the least developed countries, where life expectancy today is just under 50 years, it is expected to increase to 66 years by 2045–2050.
- The population of 51 countries or areas is expected to be lower in 2050 than in 2005.
- During 2005–2050, the net number of international migrants to more developed regions is projected to be 98 million. Because deaths are projected to exceed births in the more developed regions by 73 million during 2005–2050, population growth in those regions will largely be due to international migration.
- In 2000–2005, net migration in 28 countries either prevented a population decline or doubled at least the contribution of natural increase (births minus deaths) to population growth.
- Birth rates are now falling in a small percentage of developing countries, while the actual populations in many developed countries would fall without immigration.

4.3.4.4 **Urban growth**

In 1800 only 3% of the world's population lived in cities. By the 20th century's close, 47% did so. In 1950, there were 83 cities with populations exceeding one million; but by 2007, this had risen to 468 agglomerations of more than one million. If the trend continues, the world's urban population will double every 38 years, according to researchers. The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities.

The increase will be most dramatic in the poorest and least-urbanized continents, Asia and Africa. Projections indicate that most urban growth over the next 25 years will be in developing countries. One billion people, one-sixth of the world's population, or one-third of the urban population, now live in shanty towns, which are seen as "breeding grounds" for social problems such as crime, drug addiction, alcoholism, poverty and unemployment. In many poor countries, slums exhibit high rates of disease due to unsanitary conditions, malnutrition, and lack of basic health care.

In 2000, there were 18 megacities—conurbations such as Tokyo, Seoul, Mexico City, Mumbai, São Paulo and New York City – that have populations in excess of 10 million inhabitants. Greater Tokyo already has 35 million, more than the entire population of Canada (at 34.1 million).

By 2025, according to the *Far Eastern Economic Review*, Asia alone will have at least 10 hypocrites, those with more than 19 million, including Jakarta (24.9 million people), Dhaka (25 million), Karachi (26.5 million), Shanghai (27 million) and Mumbai (33 million). Lagos has grown from 300,000 in 1950 to an estimated 15 million today, and the Nigerian government estimates that city will have expanded to 25 million residents by 2015. Chinese experts forecast that Chinese cities will contain 800 million people by 2020.

4.3.4.5 Causes

The root causes for overpopulation are multifaceted and complex.

From a historical perspective, technological revolutions have coincided with population explosions. There have been three major technological revolutions – the tool-making revolution, the agricultural revolution, and the industrial revolution – all of which allowed humans more access to food, resulting in subsequent population explosions. For example, the use of tools, such as bow and arrow, allowed primitive hunters greater access to high energy foods (e.g. animal meat). Similarly, the transition to farming about 10,000 years ago greatly increased the overall food supply, which was used to support more people. Food production further increased with the industrial revolution as machinery, fertilizers, herbicides, and pesticides were used to increase land under cultivation as well as crop yields. In short, similar to bacteria that multiply in response to increased food supply, humans have increased their population as soon as food became more abundant as a result of technological innovations.

Important increases in human population occur whenever the birth rate exceeds the death rate for extended periods of time. Traditionally, the fertility rate is strongly influenced by cultural and social norms that are rather stable and therefore slow to adapt to changes in the social, technological, or ecological conditions. For example, when death rates fell during the 19th and 20th century – as a result of improved sanitation, child immunizations, and other advances in medicine – allowing more newborns to survive, the fertility rate did not adjust downward fast enough, resulting in important population growth. Prior to these changes, seven out of ten children died before reaching reproductive age, while today about 95% of newborns in industrialized nations reach adulthood.

Human psychology and the cycle of entrenched poverty, as well as the rest of the world's reaction to it, are also causative factors. Areas with greater burden of disease and warfare, contrary to popular belief, do not experience less population growth over the long term, but far more over a sustained period as poverty becomes further entrenched. This is because parents and siblings who have experienced calamitous conditions suffer from a kind of post traumatic stress syndrome about losing their family members and overcompensate by having "extra" babies. These extra babies and calamities fuel a vicious cycle and only in the small minority of cases does it cease. As this cycle is compounded over generations, calamities such as disaster or war take on a multiplier effect. For example, the AIDS crisis in Africa is said to have killed 30 million to date, yet during the last two decades money and initiatives to lower population growth by contraception have been sidelined in favor of combating HIV, feeding the population explosion that we see in Africa today. In 1990, its population was roughly 600 million; today it is over 1,050 million, 150 million more than if the HIV/AIDS crisis had never occurred.

The way the world reacts to crises, by engaging in proactive measures or favoring "too little too late" measures by deluding themselves that populations will shrink due to calamities (in the short term they may), have a huge impact on future fertility rates; failure to provide stability results in far higher population numbers over the long term and sustained poverty. In largely neglected Haiti, after the 2010 Haiti Tremor study by the UNFPA, urban fertility rates tripled, intensifying grave long term implications for a nation already unable to cope with the cycle of poverty. The Haitians now have an additional burden of accelerated population explosion and delayed demographic transition. According to demographer Gabriel Bidegain, such post-crisis population booms are a global trend.

4.3.4.6 **Extremes**

Population growth rates between 1950 and 2012 range from a 0.5% increase in the case of Bulgaria to a more than 100 fold increase for the United Arab Emirates (from 79,050 to 8.5 million). Roughly half of all nations have quadrupled their populations since 1950.

4.3.4.7 **Demographic transition**

The theory of demographic transition held that, after the standard of living and life expectancy increase, family sizes and birth rates decline. However, as new data have become available, it has been observed that after a certain level of development the fertility increases again. This means that both the worry that the theory generated about aging populations and the complacency it bred regarding the future ecological impact of population growth are misguided.

The factors cited in the old theory included such social factors as later ages of marriage, the growing desire of many women in such settings to seek careers outside child rearing and domestic work, and the decreased need of children in industrialized settings. The latter factor stems from the fact that children perform a great deal of work in small-scale agricultural societies, and work less in industrial ones; it has been cited to explain the decline in birth rates in industrializing regions.

Another version of demographic transition is proposed by anthropologist Virginia Abernethy in her book *Population Politics*, where she claims that the demographic transition occurs primarily in nations where women enjoy a special status. In strongly patriarchal nations, where she claims women enjoy few special rights, a high standard of living tends to result in population growth.

Many countries have high population growth rates but lower total fertility rates because high population growth in the past skewed the age demographic toward a young age, so the population still rises as the more numerous younger generation approaches maturity.

"Demographic entrapment" is a theory developed by Maurice King, Honorary Research Fellow at the University of Leeds, who posits that this phenomenon occurs when a country has a population larger than its carrying capacity, no possibility of migration, and exports too little to be able to import food. This will cause starvation. He claims that for example many sub-Saharan nations are or will become stuck in demographic entrapment, instead of having a demographic transition.

For the world as a whole, the number of children born per woman decreased from 5.02 to 2.65 between 1950 and 2005. A breakdown by region is as follows:

- Europe – 2.66 to 1.41
- North America – 3.47 to 1.99
- Oceania – 3.87 to 2.30
- Central America – 6.38 to 2.66
- South America – 5.75 to 2.49
- Asia (excluding Middle East) – 5.85 to 2.43

- Middle East & North Africa – 6.99 to 3.37
- Sub-Saharan Africa – 6.7 to 5.53

Excluding the observed reversal in fertility decrease for high development, the projected world number of children born per woman for 2050 would be around 2.05. Only the Middle East & North Africa (2.09) and Sub-Saharan Africa (2.61) would then have numbers greater than 2.05.

4.3.4.8 Carrying capacity

There is wide variability both in the definition and in the proposed size of the Earth's carrying capacity, with estimates ranging from less than 1 to 1000 billion humans (1 trillion). A 2001 UN report said that two-thirds of the estimates fall in the range of 4 billion to 16 billion (with unspecified standard errors), with a median of about 10 billion. More recent estimates are much lower, particularly if resource depletion and increased world affluence are considered.

In a study titled *Food, Land, Population and the U.S. Economy*, David Pimentel, professor of ecology and agriculture at Cornell University, and Mario Giampietro, senior researcher at the US National Research Institute on Food and Nutrition (INRAN), estimate the maximum U.S. population for a sustainable economy at 200 million. And in order to achieve a sustainable economy and avert disaster, the United States would have to reduce its population by at least one-third, and world population would have to be reduced by two-thirds.

Some groups (for example, the World Wide Fund for Nature and Global Footprint Network) have stated that the carrying capacity for the human population has been exceeded as measured using the Ecological Footprint. In 2006, WWF's "Living Planet Report" stated that in order for all humans to live with the current consumption patterns of Europeans, we would be spending three times more than what the planet can renew. Humanity as a whole was using, by 2006, 40 percent more than what Earth can regenerate.

But critics question the simplifications and statistical methods used in calculating Ecological Footprints. Therefore Global Footprint Network and its partner organizations have engaged with national governments and international agencies to test the results – reviews have been produced by France, Germany, the European Commission, Switzerland, Luxembourg, Japan and the United Arab Emirates. Some point out that a more refined method of assessing Ecological Footprint is to designate sustainable versus non-sustainable categories of consumption. However, if yield estimates were adjusted for sustainable levels of production, the yield figures would be lower, and hence the overshoot estimated by the Ecological Footprint method even higher.

4.3.4.9 Effects of human overpopulation

The raw numbers of people are only one factor in the effects of people. The lifestyle (including overall affluence and resource utilization) and the pollution (including carbon footprint) are equally important. Currently, the inhabitants of the developed nations of the world consume resources at a rate almost 32 times greater than those of the developing world, who make up the majority of the human population.

Some problems associated with or exacerbated by human overpopulation and over-consumption are:

- Inadequate fresh water for drinking as well as sewage treatment and effluent discharge. Some countries, like Saudi Arabia, use energy-expensive desalination to solve the problem of water shortages.

- Depletion of natural resources, especially fossil fuels.
- Increased levels of air pollution, water pollution, soil contamination and noise pollution. Once a country has industrialized and become wealthy, a combination of government regulation and technological innovation causes pollution to decline substantially, even as the population continues to grow.
- Deforestation and loss of ecosystems that sustain global atmospheric oxygen and carbon dioxide stable; about eight million hectares of forest are lost each year.
- Changes in atmospheric composition and consequent global warming.
- Irreversible loss of arable land and increases in desertification. Deforestation and desertification can be reversed by adopting property rights, and this policy is successful even while the human population continues to grow.
- Mass species extinctions from reduced habitat in tropical forests due to slash-and-burn techniques that sometimes are practiced by shifting cultivators, especially in countries with rapidly expanding rural populations; present extinction rates may be as high as 140,000 species lost per year. As of February 2011, the IUCN Red List lists a total of 801 animal species having gone extinct during recorded human history.
- High infant and child mortality. High rates of infant mortality are associated with poverty. Rich countries with high population densities have low rates of infant mortality.
- Intensive factory farming to support large populations. It results in human threats including the evolution and spread of antibiotic resistant bacteria diseases, excessive air and water pollution, and new viruses that infect humans.
- Increased chance of the emergence of new epidemics and pandemics. For many ecological and social reasons, including overcrowded living conditions, malnutrition and inadequate, inaccessible, or non-existent health care, the poor are more likely to be exposed to infectious diseases.
- Starvation, malnutrition or poor diet with ill health and diet-deficiency diseases (e.g. rickets). However, rich countries with high population densities do not have famine.
- Poverty coupled with inflation in some regions and a resulting low level of capital formation. Poverty and inflation are aggravated by bad government and bad economic policies. Many countries with high population densities have eliminated absolute poverty and keep their inflation rates very low.
- Low life expectancy in countries with fastest growing populations.
- Unhygienic living conditions for many based upon water resource depletion, discharge of raw sewage and solid waste disposal. However, this problem can be reduced with the adoption of sewers. For example, after Karachi, Pakistan installed sewers, its infant mortality rate fell substantially.
- Elevated crime rate due to drug cartels and increased theft by people stealing resources to survive.
- Conflict over scarce resources and crowding, leading to increased levels of warfare.
- Less personal freedom and more restrictive laws. Laws regulate communications between humans. Law "serves as a primary social mediator of relations between people". The higher the population density, the more frequent such communications become, and thus there develops a need for more laws and/or more restrictive laws to regulate these communications. It was even speculated by Aldous Huxley in 1958 that democracy is threatened due to overpopulation, and could give rise to totalitarian style governments.

Many of these problems are explored in the dystopic science fiction film *Soylent Green*, where an overpopulated Earth suffers from food shortages, depleted resources and poverty and in the documentary "Aftermath: Population Overload".

Some economists, such as Thomas Sowell and Walter E. Williams argue that third world poverty and famine are caused in part by bad government and bad economic policies. Most biologists and sociologists see overpopulation as a serious threat to the quality of human life.

4.3.4.10 Resources

Overpopulation does not depend only on the size or density of the population, but on the ratio of population to available sustainable resources. It also depends on how resources are managed and distributed throughout the population.

The resources to be considered when evaluating whether an ecological niche is overpopulated include clean water, clean air, food, shelter, warmth, and other resources necessary to sustain life. If the quality of human life is addressed, there may be additional resources considered, such as medical care, education, proper sewage treatment, waste disposal and energy supplies. Overpopulation places competitive stress on the basic life sustaining resources, leading to a diminished quality of life.

David Pimentel, Professor Emeritus at Cornell University, has stated that "With the instable growing between population numbers and vital life sustaining resources, humans must actively conserve cropland, freshwater, energy, and biological resources. There is a need to develop renewable energy resources. Humans everywhere must understand that rapid population growth damages the Earth's resources and diminishes human well-being."

These reflect the comments also of the United States Geological Survey in their paper The Future of Planet Earth: Systematic Challenges in the Coming Century. "As the global population continues to grow...people will place greater and greater demands on the resources of our planet, including mineral and energy resources, open space, water, and plant and animal resources." "Earth's natural wealth: an audit" by *New Scientist* magazine states that many of the minerals that we use for a variety of products are in danger of running out in the near future. A handful of geologists around the world have calculated the costs of new technologies in terms of the materials they use and the implications of their spreading to the developing world. All agree that the planet's booming population and rising standards of living are set to put unprecedented demands on the materials that only Earth itself can provide. Limitations on how much of these materials is available could even mean that some technologies are not worth pursuing long term.... "Virgin stocks of several metals appear inadequate to sustain the modern 'developed world' quality of life for all of Earth's people under contemporary technology".

On the other hand, some researchers, such as Julian L. Simon and Bjørn Lomborg believe that resources exist for further population growth. In a 2010 study, they concluded that "there are not (and will never be) too many people for the planet to feed" according to The Independent. Some critics warn, this will be at a high cost to the Earth: "the technological optimists are probably correct in claiming that overall world food production can be increased substantially over the next few decades...[however] the ecological cost of what Paul R. and Anne H. Ehrlich describe as 'turning the Earth into a giant human feedlot' could be severe. A large expansion of agriculture to provide growing populations with improved diets is likely to lead to further deforestation, loss of species, soil erosion, and pollution from pesticides and fertilizer runoff as farming intensifies and new land is brought into production." Since we are intimately dependent upon the living systems of the Earth, some scientists have questioned the wisdom of further expansion.

According to the Millennium Ecosystem Assessment, a four-year research effort by 1,360 of the world's leading scientists commissioned to measure the actual value of natural resources to humans and the world, "The structure of the world's ecosystems changed more rapidly in the second half of the twentieth century than at any time in recorded human history, and virtually all of Earth's ecosystems have now been importantly transformed through human actions." "Ecosystem services, particularly food production, timber and fisheries, are important for employment and economic activity. Intensive use of ecosystems often produces the greatest short-term advantage, but excessive and unsustainable use can lead to losses in the long term. A country could cut its forests and deplete its fisheries, and this would show only as a positive gain to GDP, despite the loss of capital assets. If the full economic value of ecosystems were taken into account in decision-making, their degradation could be importantly slowed down or even reversed."

Another study by the United Nations Environment Program (UNEP) called the Global Environment Outlook which involved 1,400 scientists and took five years to prepare comes to similar conclusions. It "found that human consumption had far outstripped available resources. Each person on Earth now requires a third more land to supply his or her needs than the planet can supply." It faults a failure to "respond to or recognize the magnitude of the challenges facing the people and the environment of the planet... 'The systematic destruction of the Earth's natural and nature-based resources has reached a point where the economic viability of economies is being challenged – and where the bill we hand to our children may prove impossible to pay'... The report's authors say its objective is 'not to present a dark and gloomy scenario, but an urgent call to action'. It warns that tackling the problems may affect the vested importances of powerful groups, and that the environment must be moved to the core of decision-making... '

Although all resources, whether mineral or other, are limited on the planet, there is a degree of self-correction whenever a scarcity or high-demand for a particular kind is experienced. For example in 1990 known reserves of many natural resources were higher, and their prices lower, than in 1970, despite higher demand and higher consumption. Whenever a price spike would occur, the market tended to correct itself whether by substituting an equivalent resource or switching to a new technology.

4.3.4.11 **Fresh water**

Fresh water supplies, on which agriculture depends, are running low worldwide. This water crisis is only expected to worsen as the population increases.

Potential problems with dependence on desalination are reviewed below, however, the majority of the world's freshwater supply is contained in the polar ice caps, and underground river systems accessible through springs and wells.

Fresh water can be obtained from salt water by desalination. For example, Malta derives two thirds of its fresh water by desalination. A number of nuclear powered desalination plants exist; However, the high costs of desalination, especially for poor countries, make impractical the transport of large amounts of desalinated seawater to interiors of large countries. The cost of desalinization varies; Israel is now desalinating water for a cost of 53 cents per cubic meter, Singapore at 49 cents per cubic meter. In the United States, the cost is 81 cents per cubic meter ($3.06 for 1,000 gallons).

According to a 2004 study by Zhou and Tol, "one needs to lift the water by 2000 m, or transport it over more than 1600 km to get transport costs equal to the desalination costs. Desalinated water is expensive in places that are both somewhat far from the sea and somewhat high, such as Riyadh and Harare. In other places, the dominant cost is desalination, not transport. This leads to somewhat lower costs in places like Beijing, Bangkok, Zaragoza, Phoenix, and, of course, coastal cities like Tripoli." Thus while the study is generally positive about the technology for affluent areas that are proximate to the oceans, it concludes that "Desalinated water may be a solution for some water-stress regions, but not for places that are poor, deep in the interior of a continent, or at high elevation. Unfortunately, that includes some of the places with biggest water problems." Another potential problem with desalination is the by product of saline brine, which can be a major cause of marine pollution when dumped back into the oceans at high temperatures."

The world's largest desalination plant is the Jebel Ali Desalination Plant (Phase 2) in the United Arab Emirates, which can produce 300 million cubic meters of water per year, or about 2500 gallons per second. The largest desalination plant in the US is the one at Tampa Bay, Florida, which began desalinizing 25 million gallons (95000 m^3) of water per day in December 2007. A 17 January 2008, article in the *Wall Street Journal* states, "Worldwide, 13,080 desalination plants produce more than 12 billion gallons of water a day, according to the International Desalination Association." After being desalinized at Jubail, Saudi Arabia, water is pumped 200 miles (320 km) inland though a pipeline to the capital city of Riyadh.

However, new data originating from the GRACE experiments and isotopic testing done by the IAEA show that the Nubian aquifer—which is under the largest, driest part of the earth's surface, has enough water in it to provide for "at least several centuries". In addition to this, new and highly detailed maps of the earth’s underground reservoirs will be soon created from these technologies that will further allow proper budgeting of cheap water.

4.3.4.12 **Food**

Some scientists argue that there is enough food to support the world population, but critics dispute this, particularly if sustainability is taken into account.

Many countries rely heavily on imports. Egypt and Iran rely on imports for 40% of their grain supply. Yemen and Israel import more than 90%. And just 6 countries – Argentina, Australia, Canada, France, Thailand and the USA – supply 90% of grain exports. In recent decades the US alone supplied almost half of world grain exports.

A 2001 United Nations report says population growth is "the main force driving increases in agricultural demand" but "most recent expert assessments are cautiously optimistic about the ability of global food production to keep up with demand for the foreseeable future (that is to say, until approximately 2030 or 2050)", assuming declining population growth rates.

However, the observed figures for 2007 show an actual increase in absolute numbers of undernourished people in the world, 923 million in 2007 versus 832 million in 1995.; the more recent FAO estimates point to an even more dramatic increase, to 1.02 billion in 2009.

4.3.4.13 ***Global perspective***

The amounts of natural resources in this context are not necessarily fixed, and their distribution is not necessarily a zero-sum game. For example, due to the Green Revolution and the fact that more and more land is appropriated each year from wild lands for agricultural purposes, the worldwide production of food had steadily increased up until 1995. World food production per person was considerably higher in 2005 than 1961.

As world population doubled from 3 billion to 6 billion, daily calorie consumption in poor countries increased from 1,932 to 2,650, and the percentage of people in those countries who were malnourished fell from 45% to 18%. This suggests that Third World poverty and famine are caused by underdevelopment, not overpopulation. However, others question these statistics. From 1950 to 1984, as the Green Revolution transformed agriculture around the world, grain production increased by over 250%. The world population has grown by about four billion since the beginning of the Green Revolution and most believe that, without the Revolution, there would be greater famine and malnutrition than the UN presently documents.

The number of people who are overweight has surpassed the number who are undernourished. In a 2006 news story, MSNBC reported, "There are an estimated 800 million undernourished people and more than a billion considered overweight worldwide." The U.S. has one of the highest rates of obesity in the world. However, studies show that wealthy and educated people are far likelier to eat healthy food, indicating obesity is a disease related to poverty and lack of education as cheap high calorie foods with little nutritive value are consumed.

The Food and Agriculture Organization of the United Nations states in its report *The State of Food Insecurity in the World 2006*, that while the number of undernourished people in the developing countries has declined by about three million, a smaller proportion of the population of developing countries is undernourished today than in 1990–92: 17% against 20%. Furthermore, FAO's projections suggest that the proportion of hungry people in developing countries could be halved from 1990–92 levels to 10% by 2015. The FAO also states, "We have emphasized first and foremost that reducing hunger is no longer a question of means in the hands of the global community. The world is richer today than it was ten years ago. There is more food available and still more could be produced without excessive upward pressure on prices. The knowledge and resources to reduce hunger are there. What is lacking is sufficient political will to mobilize those resources to the benefit of the hungry."

As of 2008, the price of grain has increased due to more farming used in biofuels, world oil prices at over $100 a barrel, global population growth, climate change, loss of agricultural land to residential and industrial development, and growing consumer demand in China and India Food riots have recently taken place in many countries across the world. An epidemic of stem rust on wheat caused by race Ug99 is currently spreading across Africa and into Asia and is causing major concern. A virulent wheat disease could destroy most of the world's main wheat crops, leaving millions to starve. The fungus has spread from Africa to Iran, and may already be in Afghanistan and Pakistan.

It is becoming increasingly difficult to maintain food security in a world beset by a confluence of "peak" phenomena, namely peak oil, peak water, peak phosphorus, peak grain and peak fish. Growing populations, falling energy sources and food shortages will create a "perfect storm" by 2030, according to the UK government chief scientist. He said food reserves are at a 50-year low but the world requires 50% more energy, food and water by 2030. The world will have to produce 70% more food by 2050 to feed a projected extra 2.3 billion people, the United Nations' Food and Agriculture Organization (FAO) warned.

4.3.4.13 Environment

Overpopulation has substantially adversely affected the environment of Earth starting at least as early as the 20th century. There are also economic consequences of this ecological degradation in the form of ecosystem services attrition. Beyond the systematically verifiable harm to the environment, some assert the moral right of other species to simply exist rather than become extinct. Ecological author Jeremy Rifkin has said "our burgeoning population and urban way of life have been purchased at the expense of vast ecosystems and habitats. ... It's no accident that as we celebrate the urbanization of the world, we are quickly approaching another historic watershed: the disappearance of the wild."

Says Peter Raven, former President of the American Association for the Advancement of Science (AAAS) in their seminal work AAAS Atlas of Population & Environment, "Where do we stand in our efforts to achieve a sustainable world? Clearly, the past half century has been a traumatic one, as the collective impact of human numbers, affluence (consumption per individual) and our choices of technology continue to exploit rapidly an increasing proportion of the world's resources at an unsustainable rate. ... During a remarkably short period of time, we have lost a quarter of the world's topsoil and a fifth of its agricultural land, altered the composition of the atmosphere profoundly, and destroyed a major proportion of our forests and other natural habitats without replacing them. Worst of all, we have driven the rate of biological extinction, the permanent loss of species, up several hundred times beyond its historical levels, and are threatened with the loss of a majority of all species by the end of the 21st century."

Further, even in countries, which have both large population growth and major ecological problems, it is not necessarily true that curbing the population growth will make a major contribution towards resolving all ecological problems. However, as developing countries with high populations become more industrialized, pollution and consumption will invariably increase.

The Worldwatch Institute said the booming economies of China and India are planetary powers that are shaping the global biosphere. The report states:

> *The world's ecological capacity is simply insufficient to satisfy the ambitions of China, India, Japan, Europe and the United States as well as the aspirations of the rest of the world in a sustainable way*

It said that if China and India were to consume as much resources per capita as the United States or Japan in 2030 together they would require a full planet Earth to meet their needs. In the longterm these effects can lead to increased conflict over dwindling resources and in the worst case a Malthusian catastrophe.

Many studies link population growth with emissions and the effect of climate change.

4.3.4.14 Warfare and Conflict

It has been suggested that overpopulation leads to increased levels of tensions both between and within countries. Modern usage of the term "lebensraum" supports the idea that overpopulation may promote warfare through fear of resource scarcity and increasing numbers of youth lacking the opportunity to engage in peaceful employment (the youth bulge theory).

4.3.4.15 Criticism of this hypothesis

The hypothesis that population pressure causes increased warfare has been recently criticized on the empirical grounds. Both studies focusing on specific historical societies and analyses of cross-cultural data have failed to find positive correlation between population density and incidence of warfare. Andrey Korotayev, in collaboration with Peter Turchin, has shown that such negative results do not falsify the population-warfare hypothesis. Population and warfare are dynamical variables, and if their interaction causes sustained oscillations, then we do not in general expect to find strong correlation between the two variables measured at the same time (that is, unlagged). Korotayev and Turchin have explored mathematically what the dynamical patterns of interaction between population and warfare (focusing on internal warfare) might be in both stateless and state societies. Next, they have tested the model predictions in several empirical case studies: early modern England, Han and Tang China, and the Roman

Empire. Their empirical results have supported the population-warfare theory: that there is a tendency for population numbers and internal warfare intensity to oscillate with the same period but shifted in phase (with warfare peaks following population peaks). Furthermore, they have demonstrated that in the agrarian societies the rates of change of the two variables behave precisely as predicted by the theory: population rate of change is negatively affected by warfare intensity, while warfare rate of change is positively affected by population density.

4.3.4.16 Mitigation measures

Several mitigation measures have been or can be applied to reduce the adverse impacts of overpopulation. All of these mitigations are ways to implement social norms. Overpopulation is an issue that threatens the state of the environment in the above-mentioned ways and therefore societies must make a change in order to reverse some of the ecological effects brought on by current social norms. In societies like China, the government has put policies in place that regulate the number of children allowed to a couple. Other societies have already begun to implement social marketing strategies in order to educate the public on overpopulation effects. "The intervention can be widespread and done at a low cost. A variety of print materials (flyers, brochures, fact sheets, stickers) needs to be produced and distributed throughout the communities such as at local places of worships, sporting events, local food markets, schools and at car parks (taxis / bus stands)." Such prompts work to introduce the problem so that social norms are easier to implement. Certain government policies are making it easier and more socially acceptable to use contraception and abortion methods. An example of a country whose laws and norms are hindering the global effort to slow population growth is Afghanistan. “The approval by Afghan President Hamid Karzai of the Shia Personal Status Law in March 2009 effectively destroyed Shia women’s rights and freedoms in Afghanistan. Under this law, women have no right to deny their husbands sex unless they are ill, and can be denied food if they do.”

4.3.4.17 Birth regulations

Overpopulation is related to the issue of birth control; some nations, like the People's Republic of China, use strict measures to reduce birth rates. Religious and ideological opposition to birth control has been cited as a factor contributing to overpopulation and poverty. Some leaders and ecologicalists (as well as business magnates such as Ted Turner) have suggested that there is an urgent need to strictly implement a China-like one-child policy globally by the United Nations, because this would help control and reduce population gradually.

Indira Gandhi, late Prime Minister of India, implemented a forced sterilization programme in the 1970s. Officially, men with two children or more had to submit to sterilization, but many unmarried young men, political opponents and ignorant men were also believed to have been sterilized. This program is still remembered and criticized in India, and is blamed for creating a public aversion to family planning, which hampered Government programmes for decades.

Urban designer Michael E. Arth has proposed a "choice-based, marketable birth license plan" he calls "birth credits". Birth credits would allow any woman to have as many children as she wants, as long as she buys a license for any children beyond an average allotment that would result in zero population growth (ZPG). If that allotment was determined to be one child, for example, then the first child would be free, and the market would determine what the license fee for each additional child would cost. Extra credits would expire after a certain time, so speculators could not hoard these credits. The actual cost of the credits would only be a fraction of the actual cost of having and raising a child, so the credits would serve more as a wake-up call to women who might otherwise produce children without seriously considering the long term consequences to themselves or society.

4.3.4.18 Education and empowerment

One option is to focus on education about overpopulation, family planning, and birth control methods, and to make birth-control devices like male/female condoms, pills and intrauterine devices easily available. Worldwide, nearly 40% of pregnancies are unintended (some 80 million unintended pregnancies each year). An estimated 350 million women in the poorest countries of the world either did not want their last child, do not want another child or want to space their pregnancies, but they lack access to information, affordable means and services to determine the size and spacing of their families. In the developing world, some 514,000 women die annually of complications from pregnancy and abortion, with 86% of these deaths occurring in the sub-Saharan Africa region and South Asia. Additionally, 8 million infants die, many because of malnutrition or preventable diseases, especially from lack of access to clean drinking water. In the United States, in 2001, almost half of pregnancies were unintended.

Egypt announced a program to reduce its overpopulation by family planning education and putting women in the workforce. It was announced in June 2008 by the Minister of Health and Population Hatem el-Gabali. The government has set aside 480 million Egyptian pounds (about 90 million U.S. dollars) for the program.

4.3.4.19 Extraterrestrial settlement

In the 1970s, Gerard O'Neill suggested building space habitats that could support 30,000 times the carrying capacity of Earth using just the asteroid belt and that the Solar System as a whole could sustain current population growth rates for a thousand years. Marshall Savage (1992, 1994) has projected a human population of five quintillion throughout the Solar System by 3000, with the majority in the asteroid belt. Freeman Dyson (1999) favors the Kuiper belt as the future home of humanity, suggesting this could happen within a few centuries. In *Mining the Sky*, John S. Lewis suggests that the resources of the solar system could support 10 quadrillion (10^{16}) people.

K. Eric Drexler, famous inventor of the futuristic theory of molecular nanotechnology, has suggested in *Engines of Creation* that colonizing space will mean breaking the Malthusian limits to growth for the human species.

It may be possible for other parts of the Solar System to be inhabited by humanity at some point in the future. Geoffrey Landis of NASA's Glenn Research Center in particular has pointed out that "[at] cloud-top level, Venus is the paradise planet", as one could construct aerostat habitats and floating cities there easily, based on the theory that breathable air is a lifting gas in the dense Venusian atmosphere. Venus would, like also Saturn, Uranus, and Neptune, in the upper layers of their atmospheres, even afford a gravitation almost exactly as strong as that on Earth.

Many authors, including Carl Sagan, Arthur C. Clarke, and Isaac Asimov, have argued that shipping the excess population into space is not a viable solution to human overpopulation. According to Clarke, "the population battle must be fought or won here on Earth". The problem for these authors is not the lack of resources in space (as shown in books such as *Mining the Sky*), but the physical impracticality of shipping vast numbers of people into space to "solve" overpopulation on Earth. However, Gerard O'Neill's calculations show that Earth could offload all new population growth with a launch services industry about the same size as the current airline industry. The StarTram theory, by James R. Powell (the co-inventor of maglev transport) and others, envisions a capability to send up to 4 million people a decade to space per facility. A hypothetical extraterrestrial colony could potentially grow by reproduction alone (i.e., without any immigration), with most of the inhabitants being the direct descendants of the original colonists.

4.3.4.20 **Urbanization**

Despite the increase in population density within cities (and the emergence of megacities), UN Habitat states in its reports that urbanization may be the best compromise in the face of global population growth. Cities concentrate human activity within limited areas, limiting the breadth of ecological damage. But this mitigating influence can only be achieved if urban planning is importantly improved and city services are properly maintained.

Review Questions

1. Define the Terrestrial Hazards?
2. Explain the major natural hazards?
3. Explain the Man- Induced Hazards?
4. Explain the Desertification?

Learning Objectives

- To define Terrestrial Hazards.
- To explain the major natural hazards.
- To explain the Man- Induced Hazards.
- To describe the Desertification.

Discussion Questions

Discuss the Population Explosion?

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