Rai Technology University

ENGINEERING MINDS

World Economic Geography

Subject: WORLD ECONOMIC GEOGRAPHY **Credits: 4**

SYLLABUS

Classification of Economic

Meaning, Scope and Approaches to Economic Geography, Main Concepts of Economic Geography
Resource: Concept & Classification, Natural Resources: Soil, Forest & Water

Principal of Crops

Mineral Resources: Iron Ore & Bauxite, Power Resources: Coal, Petroleum & Hydro Electricity, Resource Conservation, Principal Crops: Wheat, Rice, Sugarcane & Tea.

Theory of Agriculture

Agricultural Regions of the World (Derwent Whittlesey), Theory of Agricultural Location (Von Thunen), Theory of Industrial Location (Weber), Major Industries: Iron & Steel, Textiles, Petro - Chemical & Sugar Industrial Regions of the World

World Transportation

Major Trans-Continental Railways, Sea & Air Routes, International Trade: Patterns & Trend, Major Trade Blocks: NAFTA, EEC, ASEAN, Effect of Globalization on Developing Countries

Suggested Readings

1. Paul Knox, John Agnew, Linda McCarthy, The Geography of the World Economy, Oxford University Press, USA
2. World Book Inc, World Development Report, Reshaping Economic Geography, World Bank Publications
3. Gunnar Alexandersson, World Resources: Energy and Minerals : Studies in Economic and Political Geography, Walter De Gruyter Inc

World Economic Geography

Chapter 1- Categorization of Economic

Learning Objectives

- To define the Economic Geography.
- To explain the idea of Economic Geography.
- To explain the Resource.
- To describe the Natural Resources.

1.1 Meaning, Scope and Approaches to Economic Geography

1.1.1 Economic geography

Economic geography is the study of the place, distribution and spatial organization of economic actions across the world. It represents a traditional subfield of the discipline of geography. However, in recent decades, also many economists have approached the field in ways more typical of the discipline of economics.

Economic geography has taken a variety of approaches to many different subject matters, including but not limited to the place of industries, economies of agglomeration (also known as "linkages"), transportation, international trade, economic development, real estate, gentrification, ethnic economies, gendered economies, core-periphery theory, the economics of urban form, the relationship between the environment and the economy (tying into a long history of geographers studying culture-environment interaction), and globalization.

1.1.2 Theoretical background and influences

The subject matter investigated is strongly influenced by the researcher's methodological approach. Neoclassical place theorists, following in the tradition of Alfred Weber, tend to focus on industrial place and use quantitative methods. Since the 1970s, two wide reactions against neoclassical approaches have significantly changed the discipline: Marxist political economy, growing out of the work of David Harvey; and the new economic geography which takes into account social, cultural, and institutional factors in the spatial economy.

Economists such as Paul Krugman and Jeffrey Sachs have also analyzed many traits related to economic geography. Krugman has gone so far as to call his application of spatial thinking in international trade theory the "new economic geography", which directly competes with an approach within the discipline of geography that is also called "new economic geography". The name geographical economics have been suggested as an alternative.

1.1.3 History

The history of economic geography was influenced by many theories, arising mainly from economics and geography.

Some of the first traces of the study of the spatial aspects of economic actions can be found in seven Chinese maps of the State of Qin dating to the 4th century BC. Ancient writings can be attributed to the Greek geographer Strabo's *Geographika* compiled almost 2000 years ago. As the science of cartography developed, geographers illuminated many aspects used today in the field; maps created by different European powers described the resources likely to be found in American, African, and Asian territories. The earliest travel journals included descriptions of the native peoples, the climate, the landscape, and the productivity of various places. These early accounts encouraged the development of transcontinental trade patterns and ushered in the era of mercantilism.

World War II contributed to the popularization of geographical knowledge generally, and postwar economic recovery and development contributed to the growth of economic geography as a discipline. During environmental determinism's time of popularity, Ellsworth Huntington and his theory of climatic determinism, while later greatly criticized, notably influenced the field. Valuable contributions also came from place theorists such as Johann Heinrich von Thünen or Alfred Weber. Other influential theories include Walter Christaller's Central place theory, the theory of core and periphery.

Fred K. Schaefer's article *Exceptionalism in geography: A Methodological Examination*, published in the American journal Annals of the Association of American Geographers, as well as his critique of regionalism, made a large impact on the field: the article became a rallying point for the younger generation of economic geographers who were intent on reinventing the discipline as a science, and quantitative methods began to prevail in research. Well-known economic geographers of this period include William Garrison, Brian Berry, Waldo Tobler, Peter Haggett and William Bunge.

Contemporary economic geographers tend to specialize in areas such as place theory and spatial study (with the help of geographic information systems), market research, geography , transportation, real estate price evaluation, regional and global development, planning, Internet geography, innovation, social networks.

1.1.4 Approaches to study

As economic geography is a very wide discipline, with economic geographers using many different methodologies in the study of economic phenomenon in the world some distinct approaches to study have evolved over time:

- *Theoretical economic geography* focuses on building theories about spatial arrangement and distribution of economic actions .
- *Regional economic geography* examines the economic conditions of particular regions or countries of the world. It deals with economic rationalization as well as local economic development.
- *Historical economic geography* examines the history and development of spatial economic structure. Using historical data, it examines how centers of population and economic activity shift, what patterns of regional specialization and localization evolve over time and what factors explain these changes.
- *Critical economic geography* is an approach taken from the point of view of contemporary critical geography and its philosophy.
- *Behavioral economic geography* examines the cognitive processes underlying spatial reasoning, place decision making, and behavior of firms and individuals.

Economic geography is sometimes approached as a branch of anthropogeography that focuses on regional systems of human economic activity. An alternative description of different approaches to the study of human economic activity can be organized around spatiotemporal study , study of production/consumption of economic items, and study of economic flow. Spatiotemporal systems of study include economic actions of region, mixed social spaces, and development.

Alternatively, study may focus on production, exchange, distribution and consumption of items of economic activity. Allowing parameters of space-time and item to vary, a geographer may also examine material flow, commodity flow, population flow and information flow from different parts of the economic activity system. Through the study of flow and production, industrial areas, rural and urban residential areas, transportation site, commercial service facilities and finance and other economic centers are linked together in an economic activity system.

1.1.5 Branches

Thematically, economic geography can be divided into these subdisciplines:

- Geography of agriculture
- Geography of industry
- Geography of international trade
- Geography of resources
- Geography of transport and communication
- Geography of finance

These areas of study may overlap with other geographical sciences.

1.1.6 Economists and economic geographers

Generally, spatially concerned economists study the effects of space *on the economy*. Geographers, on the other hand, are concerned with the economic processes' impact *of spatial structures*.

Moreover, economists and economic geographers differ in their methods in approaching spatial-economic problems in several ways. An economic geographer will often take a more holistic approach in the study of economic phenomenon, which is to conceptualize a problem in terms of space, place and scale as well as the obvious economic problem that is being examined. The economist approach, according to some economic geographers, has the main drawback of homogenizing the economic world in ways economic geographers try to avoid.

1.1.7 New economic geography

With the rise of the New Economy, economic inequalities are rising spatially. The New Economy, generally characterized by globalization, rising use of information and communications technology, growth of knowledge goods, and feminization, has enabled economic geographers to study social and spatial divisions caused by the arising New Economy, including the emerging digital divide.

The new economic geographies consist of primarily service-based sectors of the economy that use innovative technology, such as industries where people rely on computers and the internet. Within these is a switch from manufacturing-based economies to the digital economy. In these sectors, competition makes technological changes robust. These high tech sectors rely heavily on interpersonal relationships and trust, as developing things like software is very different from other kinds of industrial manufacturing—it requires intense levels of cooperation between many different people, as well as the use of tacit knowledge. As a result of cooperation becoming a necessity, there is a clustering in the high-tech new economy of many firms.

1.1.7.1 Social and spatial divisions

As characterized through the work of Diane Perrons, in Anglo-American literature, the New Economy consists of two distinct types. New Economic Geography 1 (NEG1) is characterized by sophisticated spatial modelling. It seeks to explain the uneven development and the emergence of industrial clusters. It does so through the exploration of linkages between centripetal and centrifugal forces, especially those economies of scale.

New Economic Geography 2 (NEG2) also seeks to explain the apparent paradoxical emergence of industrial clusters in a contemporary context, however, it emphasizes relational, social, and contextual aspects of economic behavior, particularly the importance of tacit knowledge. The main difference between these two types is NEG2's emphasis on aspects of economic behavior that NEG1 considers intangible.

Both New Economic Geographies acknowledge transport costs, the importance of knowledge in a new economy, possible effects of externalities, and endogenous processes that generate increases in productivity. The two also share a focus on the firm as the most important unit and on growth rather than development of regions. As a result, the actual impact of clusters on a region is given far less attention, relative to the focus on clustering of related actions in a region.

However, the focus of the firm as the main entity of significance hinders the discussion of New Economic Geography. It limits the discussion in a national and global context and confines it to a smaller scale context. It also places limits on the nature of actions carried out by the firm and their position within the global value chain. Further work done by Bjorn Asheim (2001) and Gernot Grabher (2002) challenges the idea of the firm through action-research approaches and mapping organizational forms and their linkages. In short, the focus of the firm in new economic geographies is undertheorized in NEG1 and undercontextualized in NEG2, which limits the discussion of its impact on spatial economic development.

Spatial divisions within these arising New Economic geographies are apparent in the form of the digital divide, as a result of regions attracting talented workers instead of developing skills at a local level. Despite rising inter-connected through developing information communication technologies, the contemporary world is still defined through its widening social and spatial divisions, most of which are rising early gendered. Danny Quah explains these spatial divisions through the characteristics of knowledge goods in the New Economy: goods defined by their infinite expansibility, weightlessness, and nonrivalry. Social divisions are expressed through new spatial segregation that illustrates spatial sorting by income, ethnicity, abilities, needs, and lifestyle preferences. Employment segregation can be seen through the overrepresentation of women and ethnic minorities in lower-paid service sector jobs. These divisions in the new economy are much more difficult to overcome as a result of few clear pathways of progression to higher-skilled work.

1.2 Resource: idea & Categorization

A **resource** is a source or supply from which benefit is produced. Typically resources are materials, cash, services, staff, or other assets that are transformed to produce benefit and in the process may be consumed or made unavailable. Benefits of resource utilization may include increased wealth, meeting needs or wants, proper functioning of a system, or enhanced well being. From a human perspective a natural resource is anything obtained from the environment to satisfy human needs and wants. From a wider biological or ecological perspective a resource satisfies the needs of a living organism.

The idea of resources has been applied in diverse realms, including with respect to economics, biology, computer science, land management, and human resources, and is linked to the ideas of competition, sustainability, Protection, and stewardship.

Resources have three main characteristics: utility, limited availability, and potential for exhaustion or consumption. Resources have been variously categorized as biotic versus abiotic, renewable versus non-renewable, and potential versus actual, along with more elaborate categorizations.

1.2.1 Economic resources

In economics, a resource is defined as a service, or other asset used to produce goods and services that meet human needs and wants. Economics itself has been defined as the study of how society manages its scarce resources. Classical economics recognizes three categories of resources: land, Labor, and capital. Together with entrepreneurship, land, Labor, and capital. Land includes all natural resources and is viewed as both the site of production and the source of raw materials. Labor or human resources consist of human effort provided in the creation of products, paid in wage. Capital consists of human-made goods or means of production (machinery, buildings, and other infrastructure) used in the production of other goods and services, paid in interest.

1.2.2 Economic versus biological resources

There are three fundamental differences between economic versus ecological views: 1) the economic resource definition is human-centered (anthropocentric) and the ecological resource definition is nature-centered (biocentric or ecocentric); 2) the economic view includes desire along with necessity, whereas the biological view is about basic biological needs; and 3) economic systems are based on markets of currency exchanged for goods and services, whereas biological systems are based on natural processes of growth, maintenance, and reproduction.

1.2.3 Land or natural resources

Natural resources are derived from the environment. Many natural resources are necessary for human survival, while others are used for satisfying human desire. Protection is the management of natural resources with the goal of sustainability. Natural resources may be further classified in different ways.

Resources can be categorized on the basis of origin:

- **Abiotic resources** comprise non-living things (e.g., land, water, air and minerals such as gold, iron, copper, silver).
- **Biotic resources** are obtained from the biosphere. Forests and their products, animals, birds and their products, fish and other marine organisms are important examples. Minerals such as coal and petroleum are sometimes included in this category because they were formed from fossilized organic matter, though over long periods of time.

Natural resources are also categorized based on the stage of development:

- **Potential Resources** are known to exist and may be used in the future. For example, petroleum may exist in many parts of India and Kuwait that have sedimentary rocks, but until the time it is actually drilled out and put into use, it remains a potential resource.
- **Actual resources** are those that have been surveyed, their quantity and quality determined, and are being used in present times. For example, petroleum and natural gas is actively being obtained from the Mumbai High Fields. The development of an actual resource, such as wood processing depends upon the technology available and the cost involved. That part of the actual resource that can be developed profitably with available technology is called a **reserve resource**, while that part that cannot be developed profitably because of lack of technology is called a **stock resource**.

Natural resources can be categorized on the basis of renewability:

- **Non-renewable Resources** are formed over very long geological periods. Minerals and fossils are included in this category. Since their rate of formation is extremely slow, they cannot be replenished, once they are depleted. Out of these, the metallic minerals can be re-used by recycling them, but coal and petroleum cannot be recycled.
- **Renewable resources**, such as forests and fisheries, can be replenished or reproduced relatively quickly. The highest rate at which a resource can be used sustainably is the sustainable yield. Some resources, like sunlight, air, and wind, are called **perpetual resources** because they are available continuously, though at a limited rate. Their quantity is not affected by human consumption. Many renewable resources can be depleted by human use, but may also be replenished, thus maintaining a flow. Some of these, like agricultural crops, take a short time for renewal; others, like water, take a comparatively long time, while still others, like forests, take even longer.

Depending upon the speed and quantity of consumption, overconsumption can lead to exhaustion or total and everlasting destruction of a resource. Important examples are agricultural areas, fish and other animals, forests, healthy water and land, cultivated and natural landscapes. Such **conditionally renewable resources** are sometimes classified as a third kind of resource, or as a subtype of renewable resources. Conditionally renewable resources are presently subject to excess human consumption and the only sustainable long term use of such resources is within the so-called zero ecological footprint, wherein human use less than the Earth's ecological capacity to regenerate.

Natural resources are also categorized based on distribution :

- **Ubiquitous Resources** are found everywhere (e.g., air, light, water).
- **Localized Resources** are found only in certain parts of the world (e.g., copper and iron ore, geothermal power).

On the basis of ownership, resources can be classified as individual, community, national, and international.

1.2.4 Labor or human resources

Human beings, through the labor they provide and the organizations they staff, are also considered to be resources. The term Human resources can also be defined as the skills, energies, talents, abilities and knowledge that are used for the production of goods or the rendering of services.

In a project management context, human resources are those employees responsible for undertaking the actions defined in the project plan.

1.2.5 **Capital or infrastructure**

In economics, capital refers to already-produced durable goods used in production of goods or services. As resources, capital goods may or may not be significantly consumed, though they may depreciate in the production process and they are typically of limited capacity or unavailable for use by others.

1.2.6 Tangible versus intangible resources

Whereas, tangible resources such as equipment have actual physical existence, intangible resources such as corporate images, brands and patents, and other intellectual property exist in abstraction.

Generally the economic value of a resource is controlled by supply and demand. Some view this as a narrow perspective on resources because there are many intangibles that cannot be measured in cash. Natural resources such as forests and mountains have aesthetic value. Resources also have an ethical value.

1.3 Natural Resources: Land, Forest & Water

1.3.1 Natural resource

Natural resources occur naturally within environments that exist relatively undisturbed by humanity, in a natural form. A natural resource is often characterized by the amounts of biodiversity and geodiversity existent in various ecosystems.

Natural resources are derived from the environment. Some of them are necessary for our survival while most are used for satisfying our wants. Natural resources may be further classified in different ways.

Natural resources are materials and components (something that can be used) that can be found within the environment. Every man-made product is composed of natural resources (at its fundamental level). A **natural resource** may exist as a separate entity such as fresh water, and air, as well as a living organism such as a fish, or it may exist in an alternate form which must be processed to obtain the resource such as metal ores, oil, and most forms of energy.

There is much debate worldwide over natural resource, this is partly due to rising scarcity (exhaustion of resources) but also because the exportation of natural resources is the basis for many economies (particularly for developed nations such as Australia).

Some natural resources such as sunlight and air can be found everywhere, and are known as ubiquitous resources. However, most resources only occur in small sporadic areas, and are referred to as localized resources. There are very few resources that are considered inexhaustible (will not run out in the foreseeable future) – these are solar radiation, geothermal energy, and air (though access to clean air may not be). The vast majority of resources are exhaustible, which means they have a finite quantity, and can be depleted if managed improperly.

1.3.1.1 **Categorization**

There are various methods of categorizing natural resources, these include source of origin, stage of development, and by their renewability. These categorizations are described below. On the basis of origin, resources may be divided into:

- A biotic – Biotic resources are obtained from the biosphere (living and organic material), such as forests and animals, and the materials that can be obtained from them. Fossil fuels such as coal and petroleum are also included in this category because they are formed from decayed organic matter.
- Abiotic – Abiotic resources are those that come from non-living, non-organic material. Examples of abiotic resources include land, fresh water, air and heavy metals including areas such as gold, iron, copper, silver, etc.

Considering their stage of development, natural resources may be referred to in the following ways:

- *Potential Resources* – Potential resources are those that exist in a region and may be used in the future. For example, petroleum may exist in many parts of India, having sedimentary rocks but until the time it is actually drilled out and put into use, it remains a potential resource.
- *Actual Resources* – Actual resources are those that have been surveyed, their quantity and quality determined and are being used in present times. The development of an actual resource, such as wood processing depends upon the technology available and the cost involved.
- *Reserve Resources* – The part of an actual resource which can be developed profitably in the future is called a reserve resource.
- *Stock Resources* – Stock resources are those that have been surveyed but cannot be used by organisms due to lack of technology. For example: hydrogen.

Renewability is a very popular topic and many natural resources can be categorized as either renewable or non-renewable:

- Renewable resources are ones that can be replenished naturally. Some of these resources, like sunlight, air, wind, etc., are continuously available and their quantity is not noticeably affected by human consumption. Though many renewable resources do not have such a rapid recovery rate, these resources are susceptible to exhaustion by over-use. Resources from a human use perspective are classified as renewable only so long as the rate of replenishment/recovery exceeds that of the rate of consumption.
- Non-renewable resources are resources that form extremely slowly and those that do not naturally form in the environment. Minerals are the most common resource included in this category. By the human perspective, resources are non-renewable when their rate of consumption exceeds the rate of replenishment/recovery; a good example of this are fossil fuels, which are in this category because their rate of formation is extremely slow (potentially millions of years), meaning they are considered non-renewable. Some resources actually naturally deplete in amount without human interference, the most notable of these being radio-active elements such as uranium, which naturally decay into heavy metals. Of these, the metallic minerals can be re-used by recycling them, but coal and petroleum cannot be recycled.

1.3.1.2 **Extraction**

Resource extraction involves any activity that withdraws resources from nature. This can range in scale from the traditional use of preindustrial societies, to global industry. Extractive industries are, along with agriculture, the basis of the primary sector of the economy. Extraction produces raw material which is then processed to add value. Examples of extractive industries are hunting and trapping, mining, oil and gas drilling, and forestry. Natural resources can add substantial's to a country's wealth, however a sudden inflow of cash caused by a resource boom can create social problems including inflation harming other industries ("Dutch disease") and corruption, leading to inequality and underdevelopment, this is known as the "resource curse".

1.3.1.3 **Exhaustion**

In recent years, the exhaustion of natural resources has become a major focus of governments and organizations such as the United Nations (UN). This is evident in the UN's Agenda 21 Section Two, which outlines the necessary steps to be taken by countries to sustain their natural resources. The exhaustion of natural resources is considered to be a sustainable development issue. The term sustainable development has many interpretations, most notably the Brundtland Commission's 'to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs', however in wide terms it is balancing the needs of the planet's people and species now and in the future. In regards to natural resources, exhaustion is of concern for sustainable development as it has the ability to degrade current environments and potential to impact the needs of future generations. Exhaustion of Natural Resources is associated with social inequity. Considering most biodiversity are located in developing countries, exhaustion of this resource could result in losses of ecosystem services for these countries. Some view this exhaustion as a major source of social unrest and conflicts in developing nations.

At present, with it being the year of the forest, there is a particular concern for rainforest regions which hold most of the Earth's biodiversity. According to Nelson deforestation and degradation affect 8.5% of the world's forests with 30% of the Earth's surface already cropped. If we consider that 80% of people rely on medicines obtained from plants and ¾ of the world's prescription medicines have ingredients taken from plants, loss of the world's rainforests could result in a loss of finding more potential life saving medicines.

The exhaustion of natural resources is caused by 'direct drivers of change' such as Mining, petroleum extraction, fishing and forestry as well as 'indirect drivers of change' such as demography, economy, society, politics and technology. The current practice of Agriculture is another factor causing exhaustion of natural resources. For example the exhaustion of nutrients in the land due to excessive use of nitrogen and desertification The exhaustion of natural resources is a continuing concern for society. This is seen in the cited quote given by Theodore Roosevelt, a well-known Protectionist and former United States president, was opposed to unregulated natural resource extraction.

1.3.1.4 **Protection**

In 1982 the UN developed the World Charter for Nature in which it recognized the need to protect nature from further exhaustion due to human activity. They state the measures needed to be taken at all societal levels, from international right down to the individual, to protect nature. They outline the need for sustainable use of natural resources and suggest that the protection of resources should be incorporated into the law system at state and international level. To look at the importance of protecting natural resources further. The World Ethic of Sustainability, developed by the IUCN, WWF and the UNEP in 1990 which set out eight values for sustainability, include the need to protect natural resources from exhaustion . Since these documents, there have been many measures taken to protect natural resources, some of these ways include Protection biology and Habitat Protection.

Protection biology is the scientific study of the nature and status of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction. It is an interdisciplinary subject drawing on sciences, economics, and the practice of natural resource management. The term *Protection biology* was introduced as the title of a conference held University of California at San Diego in La Jolla, California in 1978 organized by biologists Bruce Wilcox and Michael Soulé.

Habitat Protection is a land management practice that seeks to conserve, protect and restore, habitat areas for wild plants and animals, especially Protection reliant species, and prevent their extinction, fragmentation or reduction in range.

1.3.1.5 **Management**

Natural resource management is a discipline in the management of natural resources such as land, water, land, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations.

Management of natural resources involves identifying who has the right to use the resources and who does not for defining the boundaries of the resource. The resources are managed by the users according to the rules governing of when and how the resource is used depending on local condition.

A successful management of natural resources should engage the community because of the nature of the shared resources the individuals who are affected by the rules can participate in setting or changing them. The users have the rights to device their own management institutions and plans under the recognition by the government. The right to resources includes land, water, fisheries and pastoral rights. The users or parties accountable to the users have to actively monitor and ensure the utilization of the resource compliance with the rules and to impose penalty on those peoples who violates the rules. These conflicts are resolved in a quick and low cost manner by the local institution according to the seriousness and context of the offence. The global science-based platform to discuss natural resources management is the World Resources Forum, based in Switzerland.

1.3.2 Soil

Soil is a natural body consisting of layers (land horizons) that are primarily composed of minerals, mixed with at least some organic matter, which differ from their parent materials in their texture, structure, consistency, color, chemical, biological and other characteristics. It is the loose covering of fine rock particles that covers the surface of the earth. Land is the end product of the influence of the climate, relief (slope), organisms, parent materials (original minerals), and time.
Pedology is the study of lands in their natural environment. In engineering terms, land is referred to as regolith, or loose rock material that lies above the 'solid geology'. In horticulture, the term 'land' is defined as the layer that contains organic material that influences and has been influenced by plant roots, and may range in depth from centimeters to many meters.

Land is composed of particles of broken rock (parent materials) which have been altered by physical, chemical and biological processes that include weathering with associated erosion. Land is created from the alteration of parent material by the interactions between the lithosphere, hydrosphere, atmosphere, and biosphere. Land is commonly referred to as "earth" or "dirt"; technically, the term "dirt" should be restricted to displaced land.

Land forms a structure filled with pore spaces and can be thought of as a mixture of solids (mineral and organic), water, and gases. Accordingly, lands are often treated as a three-state system. Most lands have a density between 1 and 2 g/cm. Little of the land of planet Earth is older than the Pleistocene and none is older than the Cenozoic, although fossilized lands are preserved from as far back as the Archean.

1.3.3 Forest

Forestry is the science, art, and craft of creating, managing, using, conserving, and repairing forests and associated resources to meet desired goals, needs, and values for human benefit. Forestry is practiced in plantations and natural stands. The main goal of forestry is to create and implement systems that manage forests to provide environmental supplies and services. The challenge of forestry is to create systems that are socially accepted while sustaining the resource and any other resources that might be affected.

Silvicultureis a process for creating, maintaining, or restoring an appropriate balance of necessary components, structures, and functions that ensure long-term ecosystem vitality, stability and resiliency(Nyland, 2007). This is done at the stand level which can contain many varieties of trees. Modern forestry generally embraces a wide range of concerns, including ecosystem services by assisting forests to provide timber as raw material for wood products, wildlife habitat, natural water quality management, recreation, landscape and community protection, employment, aesthetically appealing landscapes, biodiversity management, watershed management, erosion control, and preserving forests as 'sinks' for atmospheric carbon dioxide. A practitioner of forestry is known as a forester.

Forest ecosystems have come to be seen as the most important component of the biosphere, and forestry has emerged as a vital field of science, applied art, and technology.

Forests can be classified in different ways and to different degrees of specificity. One such way is in terms of the "biome" in which they exist, combined with the leaf longevity of the dominant species (whether they are evergreen or deciduous). Another distinction is whether the forests are composed predominantly of wide leafy trees, coniferous (needle-leaved) trees, or mixed.

- Boreal forests occupy the subarctic zone and are generally evergreen and coniferous.
- Temperate zones support both wide leaf deciduous forests (*e.g.*, temperate deciduous forest) and evergreen coniferous forests (*e.g.*, temperate coniferous forests and temperate rainforests). Warm temperate zones support wide leaf evergreen forests, including laurel forests.
- Tropical and subtropical forests include tropical and subtropical moist forests, tropical and subtropical dry forests, and tropical and subtropical coniferous forests.
- Physiognomy classifies forests based on their overall physical structure or developmental stage (e.g. old growth vs. second growth).
- Forests can also be classified more specifically based on the climate and the dominant tree species present, resulting in numerous different forest types (e.g., ponderosa pine/Douglas-fir forest).

A number of global forest categorization systems have been proposed, but none has gained universal acceptance. UNEP-WCMC's forest category categorization system is a simplification of other more complex systems (e.g. UNESCO's forest and woodland 'subformations'). This system divides the world's forests into 26 major types, which reflect climatic zones as well as the principal types of trees. These 26 major types can be reclassified into 6 wideer categories: temperate needleleaf; temperate wideleaf and mixed; tropical moist; tropical dry; sparse trees and parkland; and forest plantations.

1.3.4 Water

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental actions . The majority of human uses requires fresh water.

97 percent of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air.

Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with exhaustion occurring most prominently in Asia and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. The framework for allocating water resources to water users (where such a framework exists) is known as water rights.

Surface water is water in a river, lake or freshwater wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and sub-surface seepage.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the land beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

Human actions can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing stream flow.

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for an average consumption of natural surface water from that watershed.

A natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

Brazil is the country estimated to have the largest supply of fresh water in the world, followed by Russia and Canada.

1.3.4.1 **Under river flow**

Throughout the course of a river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through sub-surface rocks and gravels that underlie the river and its floodplain called the hyporheic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hyporheic zone often forms a dynamic interface between surface water and true ground-water receiving water from the ground water when aquifers are fully charged and contributing water to ground-water when ground waters are depleted. This is especially significant in karst areas where potholes and underground rivers are common.

Subsurface water, or groundwater, is fresh water located in the pore space of land and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer (sometimes called "fossil water").

Subsurface water can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is from surface water. This difference makes it easy for humans to use sub-surface water unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a sub-surface water source is the upper bound for an average consumption of water from that source.

The natural input to sub-surface water is seepage from surface water. The natural outputs from sub-surface water are springs and seepage to the oceans.

If the surface water source is also subject to substantial evaporation, a sub-surface water source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a sub-surface water source may cause the direction of seepage to ocean to reverse which can also cause land salinization. Humans can also cause sub-surface water to be "lost" (i.e. become unusable) through pollution. Humans can increase the input to a sub-surface water source by building reservoirs or detention ponds.

Land is used in agriculture, where it serves as the anchor and primary nutrient base for plants; however, as demonstrated by hydroponics, it is not necessary to plant growth if the land-contained nutrients can be dissolved in a solution. The types of land and available moisture determine the species of plants that can be cultivated.

Land material is also a critical component in the mining and construction industries. The land serves as a foundation for most construction projects. The movement of massive volumes of land can be involved in surface mining, road building and dam construction. Earth sheltering is the architectural practice of using land for external thermal mass against building walls.

Land resources are critical to the environment, as well as to food and fiber production. The land provides minerals and water to plants. Land absorbs rainwater and releases it later, thus preventing floods and drought. Land cleans the water as it percolates through it. Land is the habitat for many organisms: the major part of known and unknown biodiversity is in the land, in the form of invertebrates (earthworms, woodlice, millipedes, centipedes, snails, slugs, mites, springtails, enchytraeids, nematodes, protists), bacteria, archaea, fungi and algae; and most organisms living above ground have part of them (plants) or spend part of their life cycle (insects) below-ground. Aboveground and below-ground biodiversities are tightly interconnected, making land protection of paramount importance for any restoration or Protection plan.

The biological component of land has been an extremely important carbon sink since about 57% of the biotic content is carbon. Even on desert crusts, cyanobacteria lichens and mosses capture and sequester a significant amount of carbon by photosynthesis. Poor farming and grazing methods have degraded lands and released much of this sequestered carbon to the atmosphere. Restoring the world's lands could offset some of the huge increase in greenhouse gases causing global warming, while improving crop yields and reducing water needs.

Waste management often has a land component. Septic drain fields treat septic tank effluent using aerobic land processes. Landfills use land for daily cover. Land application of wastewater relies on land biology to aerobically treat BOD.

Organic lands, especially peat, serve as a significant fuel resource; but wide areas of peat production, such as sphagnum bogs, are now protected because of patrimonial interest.

Both animals and humans in many cultures occasionally consume the land. It has been shown that some monkeys consume land, together with their preferred food (tree foliage and fruits), in order to alleviate tannin toxicity.

Lands filter and purify water and affect its chemistry. Rain water and pooled water from ponds, lakes and rivers percolate through the land horizons and the upper rock strata, thus becoming groundwater. Pests (viruses) and pollutants, such as persistent organic pollutants (chlorinated pesticides, polychlorinated biphenyls), oils (hydrocarbons), heavy metals (lead, zinc, cadmium), and excess nutrients (nitrates, sulfates, phosphates) are filtered out by the land. Land organisms metabolize them or immobilize them in their biomass and necromass, thereby incorporating them into stable humus. The physical integrity of the land is also a prerequisite for avoiding landslides in rugged landscapes.

Review Questions

1. Define the Economic Geography?
2. Explain the idea of Economic Geography?
3. Explain the Resource?
4. Explain the Natural Resources?

Discussion Questions

Discuss the natural resources like soil, water and forest?

Chapter 2- Principal of Crops

Learning Objectives

- To define the Mineral Resources.
- To explain the Power Resources.
- To explain the Resource Conservation.
- To describe the Principal Crops.

2.1 Mineral Resources: Iron Ore & Bauxite

2.1.1 Mineral Resources

These are the natural resources which cannot be renewed. They are present in the organisms as an organic and inorganic molecule and ions. The calcium, phosphorous, sodium, chlorine and sulphur are the major minerals in the animals. The minor minerals in the animals are iron, copper, cobalt, zinc, fluorine and selenium. The minerals in the plants are divided into the macro and micro nutrients. The macro nutrients consist of calcium, magnesium, sulphur and iron. The micronutrients consist of manganese, cobalt, zinc and chlorine. The minerals are present everywhere in the world. Their distribution varies from one country to the other. They are non equal in the distribution . India is rich in coal, manganese, iron, chromites and mica. It is deficient in the gold, silver, nickel etc. In the North America there is an abundance of molybdenum but it is deficient in the tin, manganese. However these deficient metals are found in abundance in the Indonesia and Malaysia. The gold and uranium occur in good abundance at the South Africa but it has a deficiency of silver and iron. The most common fertilizers in India are the NPK. India depends on the other countries for its supply. Our country is in the deficiency of the petroleum and electrical energy. The raw material is also deficient. New projects are undertaken to explore the new opportunities of energy. If we move at the present rate most of the important metals will last only in this century. However, some of them like manganese, aluminum, cobalt, iron and chromium can work till 2500 A.D. The minerals must be conserved and should be recycled regularly. They must be used as a raw material where there is a major need. They must be explored regularly. They must be substituted and new techniques must be used to prevent its loss.

Mining and recovery of mineral resources had been with us for a long time. Early Paleolithic man found flint for arrowheads and clay for pottery before developing codes for warfare. And this was done without geologists for exploration, mining engineers for recovery or chemists for extraction techniques. Tin and copper mines were necessary for a Bronze Age; gold, silver, and gemstones adorned the wealth of early civilizations; and iron mining introduced a new age of man.

Human wealth basically comes from agriculture, manufacturing, and mineral resources. Our complex modern society is built around the exploitation and use of mineral resources. Since the future of humanity depends on mineral resources, we must understand that these resources have limits; our known supply of minerals will be used up early in the third millennium of our calendar. Furthermore, modern agriculture and the ability to feed an overpopulated world is dependent on mineral resources to construct the machines that till the land, enrich it with mineral fertilizers, and to transport the products. As geologists, we cannot tell you that mineral resources are finite. The presently available resources were created by earth processes and after we exhaust them, more will develop in a few tens of million years, which is not in human life spans.

We are now reaching the limits of reserves for many minerals . Human population growth and increased modern industry are depleting our available resources at rising rates. Although objections have been made to the **Rome Report** of 1972, the press of human growth upon the planet's resources is a very real problem. The consumption of natural resources proceeded at a phenomenon l rate during the past hundred years and population and production increases cannot continue without rising pollution and exhaustion of mineral resources. The geometric rise of population has been joined by a period of rapid industrialization, which has placed incredible pressure on the natural resources. Limits of growth in the world are imposed not as much by pollution as by the exhaustion of natural resources. As the industrialized nations of the world continue the rapid exhaustion of energy and mineral resources, and resource-rich less-developed nations become rising early awareness of the value of their raw materials, resource driven conflicts will increase. By about the middle of the next century the critical factors come together to impose a drastic population reduction by catastrophe. We can avert this only if we embark on a planet-wide program of transition to a new physical, economic, and social world that recognizes the limits of growth of both links to population and resource use.

In a world that has finite mineral resources, exponential growth and expanding consumption is impossible. Fundamental adjustments must be made to the present growth culture to a steady-state system. This will pose problems in that industrialized nations are already feeling a loss in their standard of living and in non-industrialized nations that feel they have a right to achieve higher standards of living created by industrialization.

"Every effort to prevent pollution and produce more food and other resources is bound to be short-lived under present world population policies. Such temporary measures can provide lead time so that people can be educated to the need for limiting population to that number for which the world can provide. If this education is unsuccessful, all other measures are in vain."

This was written in 1975, and in 1999, the population growth continues upward and the supply of resources continues to diminish. With the rising shortages of many minerals, we have been driven to search for new sources. Marine resources are the potential area for new mineral sources. In the 1960's, marine mining was a major issue among businessmen, politicians and scientists with a major push by scientists to make industry aware of the potential market opportunities from the ocean. At the time of this writing, resources from the sea draw less interest except for oil and gas exploration.

The conflict between exploration and production with environmental concerns and the costs of offshore exploration have led to a reduced drive to find offshore mineral resources. Resolving the conflicts will be an integral part of developing marine mineral sources. Legal, political, and social problems involved in marine mining are complex and more difficult to resolve. An ore body on land lies within a national boundary -- political boundaries may change and mining disruptions occur like those we have seen in Africa -- in fact governments may be manipulated to control mineral wealth, but in the end, someone owns the ore body and awards a mining lease. Recent treaties and proclamations have established zones of exclusive mineral rights to neighboring nations, and negotiations have established seaward boundaries between adjacent countries, but much of the ocean lies beyond national boundaries, creating major political and legal problems for mining activity.

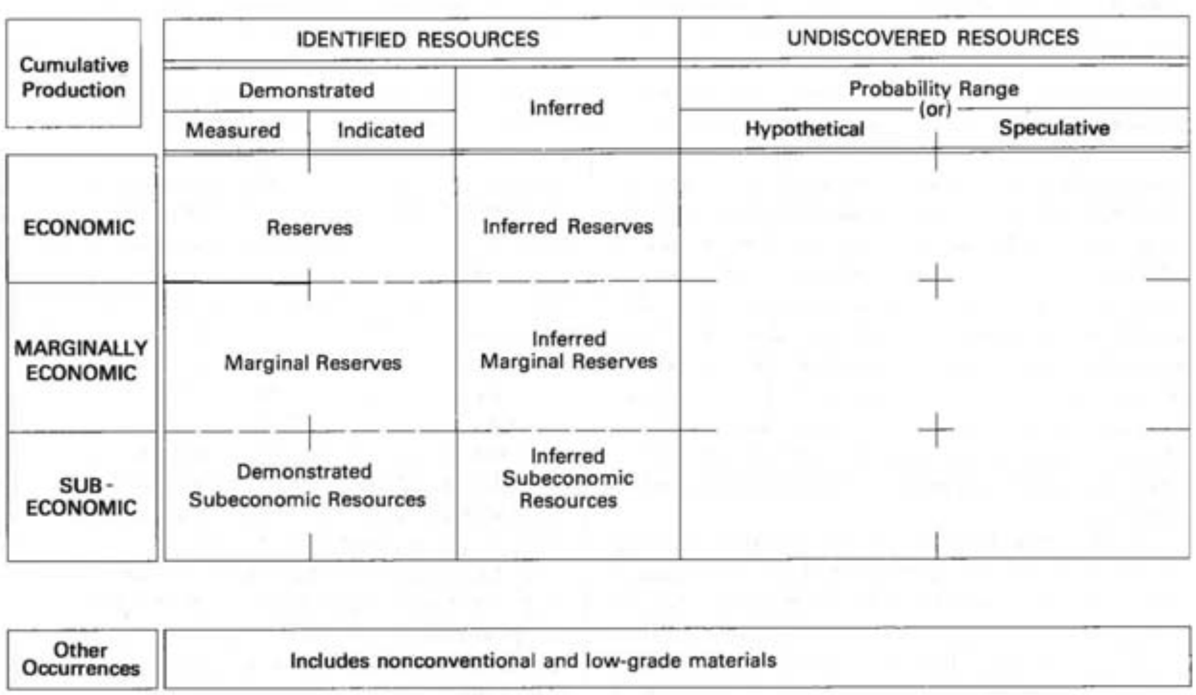
Continental margins include an area that is almost 50% as large as the existing land areas. Mineral deposits from the shelf and slope could approximate those found in adjacent terrestrial areas. These will include unconsolidated deposits of heavy minerals mostly close inshore or in estuarine or drowned river valleys, sands, gravels, shells, and similar nonmetallic deposits laid down under shallow water or subaerial conditions. In deep water, deposits of phosphorite and ferromanganese oxides and sulfides with associated minerals are the main targets of exploration. As we gather more information about mineralization processes on the deep ocean ridge systems, we open new frontiers for mineral exploration.

In 1969, Christy predicted that in two decades fisheries, oil and gas and deep sea nodules would be the important marine assets. In 1999, fish stocks are showing serious exhaustion and the mining of deep sea nodules is a future idea , only petroleum and gas exploration has intensified.

As we increase our efforts in marine mining, we must understand that although many processes are common over the entire earth, the deep ocean crust and the continental crust are of different types of rock, and geochemical processes of enrichment and sedimentary processes of transport and concentration of minerals differ. The problems of searching for and extraction of marine mineral resources are different, more difficult, and more costly. The implications of the plate tectonics idea for mineral exploration must be understood to develop exploration strategies since localization of mineral deposits is governed by tectonic processes. Rising knowledge of the mechanisms of plate tectonics has led to improved idea s for locating marine mineral deposits.

2.1.1.1 Mineral resource categorization

Mineral resource categorization is the categorization of mineral deposits based on their geologic certainty and economic value.



A "McKelvey diagram" showing the relation of mineral resource categorizations to economics and geologic certainty.

Mineral deposits can be classified as:

- **Mineral resources** that are potentially valuable, and for which reasonable prospects exist for eventual economic extraction.
- **Mineral reserves** or **Ore reserves** that are valuable *and* legally and economically and technically feasible to extract

In common mining terminology, an "ore deposit" by definition must have an 'ore reserve', and may or may not have additional 'resources'.

Categorization, because it is an economic function, is governed by statutes, regulations and industry best practice norms. There are several categorization schemes worldwide, however the Canadian CIM categorization, the Australasian Joint Ore Reserves Committee Code (JORC Code), the South African Code for the Reporting of Mineral Resources and Mineral Reserves (SAMREC) and the “chessboard” categorization scheme of mineral deposits by H. G. Dill are the general standards.

2.1.1.2 **Mineral reserves/Ore Reserves**

Mineral reserves are resources known to be economically feasible for extraction. Reserves are either **Probable Reserves *or* Proven Reserves**.

A *Probable Ore Reserve* is the part of Indicated resources that can be mined in an economically viable fashion, and in some circumstances, a Measured Mineral Resource. It includes diluting material and allowances for losses which may occur when the material is mined. A Probable Ore Reserve has a lower level of confidence than a Proved Ore Reserve but is of sufficient quality to serve as the basis for decision on the development of the deposit.

A *Proven Ore Reserve* is the part of Measured resources that can be mined in an economically viable fashion. It includes diluting materials and allowances for losses which occur when the material is mined.

A Proven Ore Reserve represents the highest confidence category of reserve estimate. The style of mineralization or other factors could mean that Proven Ore Reserves are not achievable in some deposits.

Generally the conversion of resources into reserves requires the application of various modifying factors, including:

- Mining and geological factors, such as knowledge of the geology of the deposit sufficient that it is predictable and verifiable; extraction and mine plans based on our models; quantification of Geotechnical risk—basically, managing the geological faults, joints, and ground fractures so the mine does not collapse; and consideration of technical risk—necessary lie, statistical and variography to ensure the ore is sampled properly:
- Metallurgical factors, including scrutiny of assay data to ensure accuracy of the information supplied by the laboratory—required because ore reserves are *bankable*. Necessary, once a deposit is elevated to reserve status, it is an economic entity and an asset upon which loans and equity can be drawn—generally to pay for its extraction at (hopefully) a profit;
- Economic factors;
- Environmental factors;
- Marketing factors;
- Legal factors;
- Political factors; and

- Social factors

2.1.2 I**ron ore**

Iron ores are rocks and minerals from which metallic iron can be economically extracted. The ores are usually rich in iron oxides and vary in color from dark grey, bright yellow, deep purple, to rusty red. The iron itself is usually found in the form of magnetite (Fe3O4), hematite (Fe2O 3), goethite (FeO (OH)), limonite (FeO (OH). n (H_2O)) or siderite ($FeCO_3$).

Ores carrying very high quantities of hematite or magnetite (greater than ~60% iron) are known as "natural ore" or "direct shipping ore", meaning they can be fed directly into iron-making blast furnaces. Most reserves of such ore have now been depleted. Iron ore is the raw material used to make pig iron, which is one of the main raw materials to make steel. 98% of the mined iron ore is used to make steel. Indeed, it has been argued that iron ore is "more integral to the global economy than any other commodity, except perhaps oil".

Metallic iron is virtually unknown on the surface of the Earth except as iron-nickel alloys from meteorites and very rare forms of deep mantle xenoliths. Although iron is the fourth most abundant element in the Earth's crust, comprising about 5%, the vast majority is bound in silicate or more rarely carbonate minerals. The thermodynamic barriers to separating pure iron from these minerals are formidable and energy intensive, therefore all sources of iron used by human industry exploit comparatively rarer iron oxide minerals, primarily hematite.

Prior to the industrial revolution, most iron was obtained from widely available goethite or bog ore, for example during the American Revolution and the Napoleonic wars. Prehistoric societies used laterite as a source of iron ore. Historically, much of the iron ore utilized by industrialized societies has been mined from predominantly hematite deposits with grades in excess of 70% Fe. These deposits are commonly referred to as "direct shipping ores" or "natural ores". Rising iron ore demand, coupled with the exhaustion of high-grade hematite ores in the United States, after World War II led to the development of lower-grade iron ore sources, principally the utilization of magnetite and taconite.

Iron ore mining methods vary by the type of ore being mined. There are four main types of iron ore deposits worked currently, depending on the mineralogy and geology of the ore deposits. These are magnetite, titanomagnetite, massive hematite and pisolitic ironstone deposits.

2.1.2.1 Banded iron formation

Banded iron formations (also known as **banded ironstone formations** or **BIF**s) are distinctive units of sedimentary rock that are almost always of Precambrian age. A typical BIF consists of repeated, thin layers (a few millimeters to a few centimeters in thickness) of silver to black iron oxides, either magnetite (Fe_3O_4) or hematite (Fe_2O_3), alternating with bands of iron-poor shales and cherts, often red in color, of similar thickness, and containing microbands (sub-millimeter) of iron oxides. Some of the oldest known rock formations, formed over 3,700 million years ago, include banded iron layers. Banded layers rich in iron were a common feature in sediments for much of the Earth's early history but are now rare. Phanerozoic ironstones generally have a different genesis.

Banded iron beds are an important commercial source of iron ore, such as the Pilbara region of Western Australia and the Animikie Group in Minnesota.

2.1.2.2 Relation to atmospheric oxygenation

The formations are abundant around the time of the great oxygenation event, 2,400 million years ago (mya or Ma), and become less common after 1,800 mya. Conditions of a reappearance of a sea with dissolved iron at 1,900 million years ago, and later in association with Snowball Earth BIF reappeared 750 million years ago, and that is problematic to explain.

2.1.2.3 Origins

The conventional idea is that the *banded iron* layers were formed in seawater as the result of oxygen being released by photosynthetic cyanobacteria, combining with dissolved iron in the Earth's oceans to form insoluble iron oxides, which precipitated out, forming a thin layer on the substrate, which may have been anoxic mud (forming shale and chert). Each band is similar to a varve, to the extent that the banding is assumed to result from cyclic variations in available oxygen.

It is unclear whether these *banded ironstone* formations were seasonal, followed some feedback oscillation in the ocean's complex system or followed some other cycle. It is assumed that initially the Earth started out with vast amounts of iron dissolved in the world's acidic seas.

Eventually, as photosynthetic organisms generated oxygen, the available iron in the Earth's oceans was precipitated out as iron oxides. At the tipping point where the oceans became permanently oxygenated, small variations in oxygen production produced pulses of free oxygen in the surface waters, alternating with pulses of iron oxide deposition.

2.1.2.4 Snowball Earth scenario

Until 1992, it was assumed that the rare, later (younger) banded iron deposits represented unusual conditions where oxygen was depleted locally, and iron-rich waters could form and then come into contact with oxygenated water.

An alternate explanation of these later deposits was undergoing much discussion as part of the Snowball Earth hypothesis. Several hypotheses exist for the initiation of the Snowball Earths. The initiation mechanisms which include the breakup of the early equatorial supercontinent (Rodinia), the first colonization of the land by early lichens and fungi and variations in the Earth's axial tilt are yet to be convincingly identified. In a Snowball Earth state the earth's continents, and possibly seas at low latitudes, were totally covered in an ice age.

If this was the case, Earth's free oxygen may have been nearly or totally depleted during a severe ice age circa 750 to 580 million years ago (mya). Dissolved iron then accumulated in the oxygen-poor oceans (possibly from seafloor hydrothermal vents). Following the thawing of the Earth, the seas became oxygenated once more causing the precipitation of the iron.

Another mechanism for BIF's, also proposed in the context of the Snowball Earth discussion, is by deposition of metal-rich brines in the vicinity of hydrothermally active rift zones. Alternatively, some geochemists suggest that BIFs could form by direct oxidation of iron by microbial anoxygenic phototrophs.

2.1.2.5 Effect of asteroid impact

Northern Minnesota's banded iron formations lie directly underneath a thick layer of material only recently recognized as ejecta from the Sudbury Basin impact. At the time of formation the earth had a single supercontinent with substantial continental shelves.

An asteroid (estimated at 10 km across) slammed into waters about 1,000 m deep some 1.85 billion years ago. Computer models suggest that the tsunami would have been at least 1,000 m at the epicenter, and 100 m high about 3,000 km away. Those immense waves and large underwater landslides triggered by the impact stirred the ocean, bringing oxygenated waters from the surface down to the ocean floor.

Sediments deposited on the sea floor before the impact, including BIFs contained little if any oxidized iron (Fe (III)), but were high in reduced iron (Fe (II)). This Fe (III) to Fe (II) ratio suggests that most parts of the ocean were relatively devoid of oxygen.

Marine sediments deposited after the impact included substantial amounts of Fe (III) but very little Fe (II). This suggests that sizeable amounts of dissolved oxygen were available to form sediments rich in Fe (III). Following the impact dissolved iron was mixed into the deepest parts of the ocean. This would have choked off most of the supplies of Fe (II) to shallower waters where BIFs typically accumulated.

The geological record suggests that environmental changes happened in oceans worldwide even before the Sudbury impact. The role the Sudbury Basin impact played in temporarily shutting down BIF accumulation is not fully understood.

2.1.3 Magnetite ores

The key economic parameters for magnetite ore being economic are the crystallinity of the magnetite, the grade of the iron within the banded iron formation host rock, and the contaminant elements which exist within the magnetite concentrate. The size and strip ratio of most magnetite resources is irrelevant as a banded iron formation can be hundreds of meters thick, extend hundreds of kilometers along strike, and can easily come to more than three billion or more tonnes of contained ore.

The typical grade of iron at which a magnetite-bearing banded iron formation becomes economic is roughly 25% iron, which can generally yield a 33% to 40% recovery of magnetite by weight, to produce a concentrate grading in excess of 64% iron by weight. The typical magnetite iron ore concentrate has less than 0.1% phosphorus, 3–7% silica and less than 3% aluminium.

Currently magnetite iron ore is mined in Minnesota and Michigan in the U.S., Eastern Canada and North Sweden. Magnetite bearing banded iron formation is currently mined extensively in Brazil, which exports significant quantities to Asia, and there is a nascent and large magnetite iron ore industry in Australia.

2.1.3.1 Direct shipping (hematite) ores

Direct shipping iron ore (DSO) deposits (typically composed of hematite) are currently exploited on all continents except Antarctica, with the largest intensity in South America, Australia and Asia. Most large hematite iron ore deposits are sourced from altered banded iron formations and rarely igneous accumulations.

DSO deposits are typically rarer than the magnetite-bearing BIF or other rocks which form its main source or protolith rock, but are considerably cheaper to mine and process as they require less beneficiation due to the high iron content. However, DSO ores can contain significantly higher concentrations of penalty elements, typically being higher in phosphorus, water content (especially pisolite sedimentary accumulations) and aluminum (clays within pisolites). Export grade DSO ores are generally in the 62–64% Fe range.

2.1.3.2 Magmatic magnetite ore deposits

Occasionally granite and ultrapotassic igneous rocks segregate magnetite crystals and form masses of magnetite suitable for economic concentration. A few iron ore deposits, notably in Chile, are formed from volcanic flows containing significant accumulations of magnetite phenocrysts. Chilean magnetite iron ore deposits within the Atacama Desert have also formed alluvial accumulations of magnetite in streams leading from these volcanic formations.

Some magnetite skarn and hydrothermal deposits have been worked in the past as high-grade iron ore deposits requiring little beneficiation. There are several granite-associated deposits of this nature in Malaysia and Indonesia.

Other sources of magnetite iron ore include metamorphic accumulations of massive magnetite ore such as at Savage River, Tasmania, formed by shearing of ophiolite ultramafics.

Another, minor, source of iron ores are magmatic accumulations in layered intrusions which contain a typically titanium-bearing magnetite often with vanadium. These ores form a niche market, with specialty smelters used to recover the iron, titanium and vanadium. These ores are beneficiated essentially similar to banded iron formation ores, but usually are more easily upgraded via crushing and screening. The typical titanomagnetite concentrate grades 57% Fe, 12% Ti and 0.5% V2O5.

2.1.3.3 Beneficiation

Lower-grade sources of iron ore generally require beneficiation, using techniques like crushing, milling, gravity or heavy media separation, screening, and silica froth flotation to improve the concentration of the ore and remove impurities. The results, high quality fine ore powders, are known as *fines*.

2.1.3.4 Magnetite

Magnetite is magnetic, and hence easily separated from the gangue minerals and capable of producing a high-grade concentrate with very low levels of impurities.

The grain size of the magnetite and its degree of commingling with the silica groundmass determine the grind size to which the rock must be comminuted to enable efficient magnetic separation to provide a high purity magnetite concentrate. This determines the energy inputs required to run a milling operation.

Mining of banded iron formations involves coarse crushing and screening, followed by rough crushing and fine grinding to comminute the ore to the point where the crystallized magnetite and quartz are fine enough that the quartz is left behind when the resultant powder is passed under a magnetic separator.

Generally most magnetite banded iron formation deposits must be ground to between 32 and 45 micrometers in order to produce a low-silica magnetite concentrate. Magnetite concentrates grades are generally in excess of 70% iron by weight and usually are low phosphorus, low aluminium, low titanium and low silica and demand a premium price.

2.1.3.5 Hematite

Due to the high density of hematite relative to associated silicate gangue, hematite beneficiation usually involves a combination of beneficiation techniques.

One method relies on passing the finely crushed ore over a bath of solution containing bentonite or other agent which increases the density of the solution. When the density of the solution is properly calibrated, the hematite will sink and the silicate mineral fragments will float and can be removed.

2.1.3.6 Production and consumption

Iron is the world's most commonly used metal - steel, of which iron ore is the key ingredient, representing almost 95% of all metal used per year. It is used primarily in structural engineering applications and in maritime purposes, automobiles, and general industrial applications (machinery).

Iron-rich rocks are common worldwide, but ore-grade commercial mining operations are dominated by the countries listed in the table aside. The major constraint to economics for iron ore deposits is not necessarily the grade or size of the deposits, because it is not particularly hard to geologically prove enough tonnage of the rocks exist. The main constraint is the position of the iron ore relative to the market, the cost of rail infrastructure to get it to market and the energy cost required to do so.

Mining iron ore is a high volume low margin business, as the value of iron is significantly lower than the base metals. It is highly capital intensive, and requires significant investment in infrastructure such as rail in order to transport the ore from the mine to a freight ship. For these reasons, iron ore production is concentrated in the hands of a few major players.

World production averages two billion metric tons of raw ore annually. The world's largest producer of iron ore is the Brazilian mining corporation Vale, followed by Anglo-Australian companies BHP Billiton and Rio Tinto Group. A further Australian supplier, Fortescue Metals Group Ltd has helped bring Australia's production to second in the world.

The seaborne trade in iron ore, that is, iron ore to be shipped to other countries, was 849m tonnes in 2004. Australia and Brazil dominate the seaborne trade, with 72% of the market. BHP, Rio and Vale control 66% of this market between them.

In Australia iron ore is won from three main sources: pisolite "channel iron deposit" ore derived by mechanical erosion of primary banded-iron formations and accumulated in alluvial channels such as at Pannawonica, Western Australia; and the dominant metasomatically-altered banded iron formation related ores such as at Newman, the Chichester Range, the Hamersley Range and Koolyanobbing, Western Australia. Other types of ore are coming to the fore recently, such as oxidised ferruginous hardcaps, for instance laterite iron ore deposits near Lake Argyle in Western Australia.

The total recoverable reserves of iron ore in India are about 9,602 million tones of hematite and 3,408 million tones of magnetite. Chhattisgarh, Madhya Pradesh, Karnataka, Jharkhand, Odisha, Goa, Maharashtra, Andhra Pradesh, Kerala, Rajasthan and Tamil Nadu are the principal Indian producers of iron ore. World consumption of iron ore grows 10% per annum on average with the main consumers being China, Japan, Korea, the United States and the European Union.

China is currently the largest consumer of iron ore, which translates to be the world's largest steel producing country. It is also the largest importer, buying 52% of the seaborne trade in iron ore in 2004. China is followed by Japan and Korea, which consume a significant amount of raw iron ore and metallurgical coal. In 2006, China produced 588 million tons of iron ore, with an annual growth of 38%.

2.1.3.7 Available iron ore resources

The Iron ore reserves at present seem quite vast, but some are starting to suggest that the math of continual exponential increase in consumption can even make this resource seem quite finite. For instance, Lester Brown of the Worldwatch Institute has suggested iron ore could run out within 64 years based on an extremely conservative extrapolation of 2% growth per year.

2.1.3.7.1 Available Australian iron ore resources

Geoscience Australia calculates that the country's "economic demonstrated resources" of iron currently amount to 24 gigatonnes, or 24 billion tonnes. The current production rate from the Pilbara region of Western Australia is approximately 430 million tonnes a year and rising. Experts Dr Gavin Mudd (Monash University) and Jonathon Law (CSIRO) expect it to be gone within 30 to 50 years (Mudd) and 56 years (Law). These estimates require ongoing review to take into account shifting demand for lower grade iron ore and improving mining and recovery techniques (allowing deeper mining below the groundwater table).

2.1.3.7.2 Future Pilbara production capacity

In 2011, leading Pilbara based iron ore miners - Rio Tinto, BHP Billiton and Foscues Metal Group - all announced significant capital investment in the development of existing and new mines and associated infrastructure (rail and port). Collectively this would amount to the production of 1,000 million tonnes per year (Mt/y) by 2020. Practically that would require a doubling of production capacity from a current production level of 470 Mt/y to 1,000 Mt/y (an increase of 530 Mt/y). These figures are based on the current production rates of Rio 220 Mt/y, BHP 180 Mt/y, FMG 55 Mt/y and Other 15 Mt/y rising to Rio 353 Mt/y, BHP 356 Mt/y, FMG 155 Mt/y and Other 140 Mt/y (the latter 140 Mt/y is based on planned production from recent industry entrants Hancock, Atlas and Brockman through Port Hedland and API and others through the proposed Port of Anketell).

A production rate of 1,000 Mt/y would require a significant increase in production from existing mines and the opening of a significant number of new mines. Further, a significant increase in the capacity of rail and port infrastructure would also be required. For example, Rio would be required to expand its port operations at Dampier and Cape Lambert by 140 Mt/y (from 220 Mt/y to 360 Mt/y). BHP would be required to expand its Port Hedland port operations by 180 Mt/y (from 180 Mt/y to 360 Mt/y). FMG would be required to expand its port operations at Port Hedland by 100 Mt/y (from 55 Mt/y to 155 Mt/y). That's an increase of 420 Mt/y in port capacity by the three majors Rio, BHP and FMG and about at least 110 Mt/y from the non-major producers. Based on the rule-of-thumb of 50 Mt/y per car dumper, reclaimer and ship-loader the new production would require approximately 10 new car dumpers, reclaimers and ship-loaders.

New rail capacity would also be required. Based on the rule-of-thumb of 100 Mt/y per rail line, rising production by approximately 500 Mt/y would require 5 new single rail lines. One scenario is an extra rail line for all the majors: BHP (from double to triple track), Rio (double to triple track), FMG (single to double track) and at least two new lines. New lines have been proposed by Hancock to service the Roy Hill mine and QR National to service non-major producers.

A 1,000 Mt/y production rate needs to be further considered by proponents and government. Areas of further consideration include a new port space at Anketell to service the West Pilbara mines, growth at Port Hedland (BHP has announced the development of an outer harbor at Port Hedland), rail rationalization and the regulatory approval requirements for opening and maintaining a ground disturbance footprint that supports 1,000 Mt/y of production including, amongst other things, native title, aboriginal heritage and environmental protection outcomes.

2.1.4 Bauxite

Bauxite is an aluminium ore and is the main source of aluminium. This form of rock consists mostly of the minerals gibbsite $Al(OH)_3$, boehmite γ-AlO(OH), and diaspore α-AlO(OH), in a mixture with the two iron oxides goethite and haematite, the clay mineral kaolinite, and small amounts of anatase TiO_2. Bauxite was named after the village Les Baux in southern France, where it was first recognized as containing aluminium and named by the French geologist Pierre Berthier in 1821.

2.1.4.1 Bauxite formation

Lateritic bauxites (silicate bauxites) are distinguished from karst bauxite ores (carbonate bauxites). The earliest discovered carbonate bauxites occur predominantly in Europe and Jamaica above carbonate rocks (limestone and dolomite), where they were formed by lateritic weathering and residual accumulation of intercalated clays or by clay dissolution residues of the limestone.

The lateritic bauxites are found mostly in the countries of the tropics. They were formed by lateritization of various silicate rocks such as granite, gneiss, basalt, syenite, and shale. In comparison with the iron-rich laterites, the formation of bauxites depends even more on intense weathering conditions in a place with very good drainage. This enables the dissolution of the kaolinite and the precipitation of the gibbsite. Zones with highest aluminium content are frequently located below a ferruginous surface layer. The aluminium hydroxide in the lateritic bauxite deposits is almost exclusively gibbsite.

In the case of Jamaica, a recent study of the lands showed elevated levels of cadmium suggesting that the bauxite originates from recent Miocene ash deposits from episodes of significant volcanism in Central America.

2.1.4.2 Production trends

In 2009, Australia was the top producer of bauxite with almost one-third of the world's production, followed by China, Brazil, India, and Guinea. Although aluminium demand is rapidly rising , known reserves of its bauxite ore are sufficient to meet the worldwide demands for aluminium for many centuries. Increased aluminium recycling, which has the advantage of lowering the cost in electric power in producing aluminium, will considerably extend the world's bauxite reserves.

2.1.4.3 Processing

Bauxite is usually strip mined because it is almost always found near the surface of the terrain, with little or no overburden. Approximately 70% to 80% of the world's dry bauxite production is processed first into alumina, and then into aluminium by electrolysis as of 2010. Bauxite rocks are typically classified according to their intended commercial application: metallurgical, abrasive, cement, chemical, and refractory.

Usually, bauxite ore is heated in a pressure vessel along with a sodium hydroxide solution at a temperature of 150 to 200 °C. At these temperatures, the aluminium is dissolved as an aluminate (the Bayer process). After separation of ferruginous residue (red mud) by filtering, pure gibbsite is precipitated when the liquid is cooled, and then seeded with fine-grained aluminium hydroxide. The gibbsite is usually converted into aluminium oxide, Al_2O_3, by heating. This mineral is dissolved at a temperature of about 960 °C in molten cryolite. Next, this molten substance can yield metallic aluminium by passing an electric current through it in the process of electrolysis, which is called the Hall–Héroult process after its American and French discoverers in 1886.

Prior to the Hall–Héroult process, elemental aluminium was made by heating ore along with elemental sodium or potassium in a vacuum. The method was complicated and consumed materials that were themselves expensive at that time. This made early elemental aluminium more expensive than gold.

2.2 Power Resources: Coal, Petroleum & Hydro Electricity

2.2.1 Coal

Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called **coal beds** or **coal seams**. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen.

Throughout history, coal has been a useful resource. It is primarily burned for the production of electricity and/or heat, and is also used for industrial purposes, such as refining metals. A fossil fuel, coal forms when the dead plant matter is converted into peat, which in turn is converted into lignite, then sub-bituminous coal, after that bituminous coal, and lastly anthracite. This involves biological and geological processes that take place over a long period.

Coal is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide anthropogenic sources of carbon dioxide releases. In 1999 world gross carbon dioxide emissions from coal usage were 8,666 million tonnes of carbon dioxide. Coal-fired electric power generation emits around 2,000 pounds of carbon dioxide for every megawatt-hour generated, which is almost double the approximately 1100 pounds of carbon dioxide released by a natural gas-fired electric plant per megawatt-hour generated. Because of this higher carbon efficiency of natural gas generation, as the fuel mix in the United States has changed to reduce coal and increase natural gas generation, carbon dioxide emissions have fallen. Those measured in the first quarter of 2012 were the lowest of any recorded in the first quarter of any year since 1992.

Coal is extracted from the ground by coal mining, either underground by shaft mining, or at ground level by open pit mining extraction. Since 1983 the world top coal producer has been China, in 2011 China produced 3,520 million of tonnes of coal – 49.5% of 7,695 million tonnes world coal production. In 2011 other large producers were United States (993 million tonnes), India (589), European Union (576) and Australia (416). In 2010 largest exporters were Australia with 328 million tonnes (27.1% of world coal export) and Indonesia with 316 million tonnes (26.1%), while largest importers were Japan with 207 million tonnes (17.5% of world coal import), China with 195 million tonnes (16.6%) and South Korea with 126 million tonnes (10.7%).

2.2.1.1 Formation

At various times in the geologic past, the Earth had dense forests in low-lying wetland areas. Due to natural processes such as flooding, these forests were buried under the land. As more and more land deposited over them, they were compressed. The temperature also rose as they sank deeper and deeper. As the process continued the plant matter was protected from biodegradation and oxidation, usually by mud or acidic water. This trapped the carbon in immense peat bogs that were eventually covered and deeply buried by sediments. Under high pressure and high temperature, dead vegetation was slowly converted to coal. As coal contains mainly carbon, the conversion of dead vegetation into coal is called carbonization.

The wide, shallow seas of the Carboniferous Period provided ideal conditions for coal formation, although coal is known from most geological periods. The exception is the coal gap in the Permian–Triassic extinction event, where coal is rare. Coal is known from Precambrian strata, which predate land plants — this coal is presumed to have originated from residues of algae.

2.2.1.2 Types

As geological processes apply pressure to the dead biotic material over time, under suitable conditions it is transformed successively into:

- Peat, considered to be a precursor of coal, has industrial importance as a fuel in some regions, for example, Ireland and Finland. In its dehydrated form, peat is a highly effective absorbent for fuel and oil spills on land and water. It is also used as a conditioner for land to make it more able to retain and slowly release water.
- Lignite, or brown coal, is the lowest rank of coal and used almost exclusively as fuel for electric power generation. A jet, a compact form of lignite, is sometimes polished and has been used as an ornamental stone since the Upper Palaeolithic.
- Sub-bituminous coal, whose properties range from those of lignite to those of bituminous coal, is used primarily as fuel for steam-electric power generation and is an important source of light aromatic hydrocarbons for the chemical synthesis industry.
- Bituminous coal is a dense sedimentary rock, usually black, but sometimes dark brown, often with well-defined bands of bright and dull material; it is used primarily as fuel in steam-electric power generation, with substantial quantities used for heat and power applications in manufacturing and to make coke.
- "Steam coal" is a grade between bituminous coal and anthracite, once widely used as a fuel for steam locomotives. In this specialized use, it is sometimes known as "sea-coal" in the US. Small steam coal (dry small steam nuts or DSSN) was used as a fuel for domestic water heating.
- Anthracite, the highest rank of coal, is a harder, glossy black coal used primarily for residential and commercial space heating. It may be divided further into metamorphically altered bituminous coal and "petrified oil", as from the deposits in Pennsylvania.
- Graphite, technically the highest rank, is difficult to ignite and is not commonly used as fuel — it is mostly used in pencils and, when powdered, as a lubricant.

2.2.1.3 Early uses as fuel

Coal from the Fushun mine in northeastern China was used to smelt copper as early as 1000 BCE. Marco Polo, the Italian who traveled to China in the 13th century, described coal—which at that time was unknown to most Europeans—as "black stones ... which burn like logs", and said coal was so plentiful, people could take three hot baths a week. In Europe, the earliest reference to the use of coal as fuel is from the geological treatise *On stones* (Lap. 16) by the Greek scientist Theophrastus (*circa* 371–287 BC):

Among the materials that are dug because they are useful, those known as *anthrakes* [coals] are made of earth, and, once set on fire, they burn like charcoal. They are found in Liguria ... and in Elis as one approaches Olympia by the mountain road; and they are used by those who work in metals.
—Theophrastus, On Stones (16) *translation*

Outcrop coal was used in Britain during the Bronze Age (3000–2000 BC), where it has been detected as forming part of the composition of funeral pyres. In Roman Britain, with the exception of two modern fields, "the Romans were exploiting coals in all the major coalfields in England and Wales by the end of the second century AD". Evidence of trade in coal (dated to about AD 200) has been found at the Roman settlement at Heronbridge, near Chester, and in the Fenlands of East Anglia, where coal from the Midlands was transported via the Car Dyke for use in drying grain. Coal cinders have been found in the hearths of villas and Roman forts, particularly in Northumberland, dated to around AD 400. In the west of England, contemporary writers described the wonder of a permanent brazier of coal on the altar of Minerva at Aquae Sulis (modern day Bath), although in fact easily accessible surface coal from what became the Somerset coalfield was in common use in quite lowly dwellings locally. Evidence of coal's use for iron-working in the city during the Roman period has been found. In Eschweiler, Rhineland, deposits of bituminous coal were used by the Romans for the smelting of iron ore.

No evidence exists of the product being of great importance in Britain before the High Middle Ages, after about AD 1000. Mineral coal came to be referred to as "seacoal" in the 13th century; the wharf where the material arrived in London was known as Sea Coal Lane, so identified in a charter of King Henry III granted in 1253. Initially, the name was given because much coal was found on the shore, having fallen from the exposed coal seams on cliffs above or washed out of underwater coal outcrops, but by the time of Henry VIII, it was understood to derive from the way it was carried to London by sea. In 1257–59, coal from Newcastle upon Tyne was shipped to London for the smiths and lime-burners building Westminster Abbey. Seacoal Lane and Newcastle Lane, where coal was unloaded at wharves along the River Fleet, are still in existence.

These easily accessible sources had largely become exhausted (or could not meet the growing demand) by the 13th century, when underground extraction by shaft mining or adits was developed. The alternative name was "pit coal", because it came from mines. It was, however, the development of the Industrial Revolution that led to the large-scale use of coal, as the steam engine took over from the water wheel. In 1700, five-sixths of the world's coal were mined in Britain. Britain would have run out of suitable sites for watermills by the 1830s if coal had not been available as a source of energy. In 1947, there were some 750,000 miners, but by 2004, this had shrunk to some 5,000 miners working in around 20 collieries.

2.2.1.4 Coal as fuel

Coal is primarily used as a solid fuel to produce electricity and heat through combustion. World coal consumption was about 7.25 billion tonnes in 2010 (7.99 billion short tons) and is expected to increase 48% to 9.05 billion tonnes (9.98 billion short tons) by 2030. China produced 3.47 billion tonnes (3.83 billion short tons) in 2011. India produced about 578 million tonnes (637.1 million short tons) in 2011. 68.7% of China's electricity comes from coal. The USA consumed about 13% of the world total in 2010, i.e. 951 million tonnes (1.05 billion short tons), using 93% of it for generation of electricity. 46% of total power generated in the USA was done using coal.

When coal is used for electricity generation, it is usually pulverized and then combusted (burned) in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time. Simple cycle steam turbines have topped out with some of the most advanced reaching about 35% thermodynamic efficiency for the entire process. Rising the combustion temperature can boost this efficiency even further. Old coal power plants, especially "grandfathered" plants, are significantly less efficient and produce higher levels of waste heat. At least 40% of the world's electricity comes from coal, and in 2012, about one-third of the United States' electricity came from coal, down from approximately 49% in 2008. As of 2012 in the United States, the use of coal to generate electricity was declining, as plentiful supplies of natural gas obtained by hydraulic fracturing of tight shale formations became available at low prices. The emergence of the supercritical turbine idea envisions running a boiler at extremely high temperatures and pressures with projected efficiencies of 46%, with further theorized increases in temperature and pressure perhaps resulting in even higher efficiencies.

In Denmark, a net electric efficiency of 47% has been obtained at the coal-fired Nordjyllandsværket CHP Plant and an overall plant efficiency of up to 91% with cogeneration of electricity and district heating. The Multifuel-fired Avedøreværket CHP Plant just outside Copenhagen can achieve a net electric efficiency as high as 49%. The overall plant efficiency with cogeneration of electricity and district heating can reach as much as 94%.

An experimental way of coal combustion is in the form of coal-water slurry fuel (CWS), which was well-developed in Russia since the days of the Soviet Union. CWS significantly reduces emissions, improving the heating value of coal. Other ways to use coal are combined heat and power cogeneration and an MHD topping cycle.

The total known deposits recoverable by current technologies, including highly polluting, low-energy content types of coal (i.e., lignite, bituminous), is sufficient for many years. However, consumption is rising and maximal production could be reached within decades.

2.2.1.5 Gasification

Coal gasification can be used to produce syngas, a mixture of carbon monoxide (CO) and hydrogen (H_2) gas. This syngas can then be converted into transportation fuels, such as gasoline and diesel, through the Fischer-Tropsch process. This technology is currently used by the Sasol chemical company of South Africa to make motor vehicle fuels from coal and natural gas. Alternatively, the hydrogen obtained from gasification can be used for various purposes, such as powering a hydrogen economy, making ammonia, or upgrading fossil fuels.

During gasification, the coal is mixed with oxygen and steam while also being heated and pressurized. During the reaction, oxygen and water molecules oxidize the coal into carbon monoxide (CO), while also releasing hydrogen gas (H_2). This process has been conducted in both underground coal mines and in the production of town gas.

$$C\ (\textit{as Coal}) + O_2 + H_2O \rightarrow H_2 + CO$$

If the refiner wants to produce gasoline, the syngas is collected at this state and routed into a Fischer-Tropsch reaction. If hydrogen is the desired end-product, however, the syngas is fed into the water gas shift reaction, where more hydrogen is liberated.

$$CO + H_2O \rightarrow CO_2 + H_2$$

In the past, coal was converted to make coal gas (town gas), which was piped to customers to burn for illumination, heating, and cooking.

2.2.1.6 Liquefaction

Coal can also be converted into synthetic fuels equivalent to gasoline or diesel by several different processes. In the direct liquefaction processes, the coal is either hydrogenated or carbonized. Hydrogenation processes are the Bergius process, the SRC-I and SRC-II (Solvent Refined Coal) processes and the NUS Corporation hydrogenation process. In the process of low-temperature carbonization, coal is coked at temperatures between 360 and 750°C (680 and 1,380°F). These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. Alternatively, coal can be converted into a gas first, and then into a liquid, by using the Fischer-Tropsch process. An overview of coal liquefaction and its future potential is available.

Coal liquefaction methods involve carbon dioxide (CO_2) emissions in the conversion process. If coal liquefaction is done without employing either carbon capture and storage (CCS) technologies or biomass blending, the result is Lifecycle greenhouse gas footprints that are generally greater than those released in the extraction and refinement of liquid fuel production from crude oil. If CCS technologies are employed, reductions of 5–12% can be achieved in Coal to Liquid (CTL) plants and up to a 75% reduction is achievable when co-gasifying coal with commercially demonstrated levels of biomass (30% biomass by weight) in coal/biomass-to-liquids plants. For future synthetic fuel projects, carbon dioxide sequestration is proposed to avoid releasing CO_2 into the atmosphere. Sequestration adds to the cost of production. Currently, all US and at least one Chinese synthetic fuel projects, include sequestration in their process designs.

2.2.2 Petroleum

Petroleum is a naturally occurring, smelly, yellow-to-black liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds, that are found in geological formations beneath the Earth's surface. The name Petroleum covers both naturally occurring unprocessed crude oils and petroleum products that are made up of refined crude oil. A fossil fuel, it is formed when large quantities of dead organisms, usually zooplankton and algae, are buried underneath a sedimentary rock and undergo intense heat and pressure.

Petroleum is recovered mostly through oil drilling. This comes after the studies of structural geology (at the reservoir scale), sedimentary basin study , reservoir characterization (mainly in terms of the porosity and permeability of geologic reservoir structures). It is refined and separated, most easily by boiling point, into a large number of consumer products, from gasoline (petrol) and kerosene to asphalt and chemical reagents used to make plastics and pharmaceuticals. Petroleum is used in manufacturing a wide variety of materials, and it is estimated that the world consumes about 90 million barrels each day.

The use of fossil fuels such as petroleum can have a negative impact on Earth's biosphere, releasing pollutants and greenhouse gases into the air and damaging ecosystems through events such as oil spills. Concern over the exhaustion of the earth's finite reserves of oil, and the effect this would have on a society dependent on it, is an idea known as peak oil.

2.2.2.1 History

2.2.2.1.1 Early history

Petroleum, in one form or another, has been used since ancient times, and is now important across society, including the economy, politics and technology. The rise in importance was due to the invention of the internal combustion engine, the rise in commercial aviation, and the importance of petroleum to industrial organic chemistry, particularly the synthesis of plastics, fertilizers, solvents, adhesives and pesticides.

More than 4000 years ago, according to Herodotus and Diodorus Siculus, asphalt was used in the construction of the walls and towers of Babylon; there were oil pits near Ardericca (near Babylon), and a pitch spring on Zacynthus. Great quantities of it were found on the banks of the river issues, one of the tributaries of the Euphrates. Ancient Persian tablets indicate the medicinal and lighting uses of petroleum in the upper levels of their society. By 347 AD, oil was produced from bamboo-drilled wells in China. Early British explorers to Myanmar documented a flourishing oil extraction industry based in Yenangyaung, that in 1795 had hundreds of hand-dug wells under production. The mythological origins of the oil fields at Yenangyaung, and its hereditary monopoly control by 24 families, indicate very ancient origins.

2.2.2.1.2 **Modern history**

In 1847, the process to distill kerosene from petroleum was invented by James Young. He noticed a natural petroleum seepage in the Riddings colliery at Alfreton, Derbyshire from which he distilled a light thin oil suitable for use as lamp oil, at the same time obtaining a thicker oil suitable for lubricating machinery. In 1848 Young set up a small business refining the crude oil.

Young eventually succeeded, by distilling cannel coal at a low heat, in creating a fluid resembling petroleum, which when treated in the same way as the seep oil gave similar products. Young found that by slow distillation he could obtain a number of useful liquids from it, one of which he named "paraffin oil" because at low temperatures it congealed into a substance resembling paraffin wax.

The production of these oils and solid paraffin wax from coal formed the subject of his patent dated 17 October 1850. In 1850 Young & Meldrum and Edward William Binney entered into partnership under the title of E.W. Binney & Co. at Bathgate in West Lothian and E. Meldrum & Co. at Glasgow; their works at Bathgate were completed in 1851 and became the first truly commercial oil-works in the world with the first modern oil refinery, using oil extracted from locally-mined torbanite, shale, and bituminous coal to manufacture naphtha and lubricating oils; paraffin for fuel use and solid paraffin were not sold till 1856.

Another early refinery was built by Ignacy Łukasiewicz, providing a cheaper alternative to whale oil. The demand for petroleum as a fuel for lighting in North America and around the world quickly grew. Edwin Drake's 1859 well near Titusville, Pennsylvania, is popularly considered the first modern well. Drake's well is probably singled out because it was drilled, not dug; because it used a steam engine; because there was a company associated with it; and because it touched off a major boom. However, there was considerable activity before Drake in various parts of the world in the mid-19th century. A group directed by Major Alexeyev of the Bakinskii Corps of Mining Engineers hand-drilled a well in the Baku region in 1848. There were engine-drilled wells in West Virginia in the same year as Drake's well. An early commercial well was hand dug in Poland in 1853, and another in nearby Romania in 1857. At around the same time the world's first, small, oil refinery was opened at Jasło in Poland, with a larger one opened at Ploiești in Romania shortly after. Romania is the first country in the world to have had its annual crude oil output officially recorded in international statistics: 275 tonnes for 1857.

The first commercial oil well in Canada became operational in 1858 at Oil Springs, Ontario (then Canada West). Businessman James Miller Williams dug several wells between 1855 and 1858 before discovering a rich reserve of oil four meters below ground. Williams extracted 1.5 million litres of crude oil by 1860, refining much of it into kerosene lamp oil. William's well became commercially viable a year before

Drake's Pennsylvania operation and could be argued to be the first commercial oil well in North America. The discovery at Oil Springs touched off an oil boom which brought hundreds of speculators and workers to the area. Advances in drilling continued into 1862 when local driller Shaw reached a depth of 62 meters using the spring-pole drilling method. On January 16, 1862, after an explosion of natural gas Canada's first oil gusher came into production, shooting into the air at a recorded rate of 3,000 barrels per day. By the end of the 19th century the Russian Empire, particularly the Branobel company in Azerbaijan, had taken the lead in production.

Access to oil was and still is a major factor in several military conflicts of the twentieth century, including World War II, during which oil facilities were a major strategic asset and were extensively bombed. Operation Barbarossa included the goal to capture the Baku oil fields, as it would provide much needed oil-supplies for the German military which was suffering from blockades. Oil exploration in North America during the early 20th century later led to the U.S. to become the leading producer by mid-century. As petroleum production in the U.S. peaked during the 1960s, however, the United States were surpassed by Saudi Arabia and the Soviet Union.

Today, about 90 percent of vehicular fuel needs are met by oil. Petroleum also makes up 40 percent of total energy consumption in the United States, but is responsible for only 1 percent of electricity generation. Petroleum's worth as a portable, dense energy source powering the vast majority of vehicles and as the base of many industrial chemicals makes it one of the world's most important commodities. The viability of the oil commodity is controlled by several key parameters, number of vehicles in the world competing for fuel, the quantity of oil exported to the world market (Export Land Model), Net Energy Gain (economically useful energy provided minus energy consumed), political stability of oil exporting nations and ability to defend oil supply lines.

The top three oil producing countries are Russia, Saudi Arabia, and the United States. About 80 percent of the world's readily accessible reserves are located in the Middle East, with 62.5 percent coming from the Arab 5: Saudi Arabia, UAE, Iraq, Qatar and Kuwait. A large portion of the world's total oil exists as unconventional sources, such as bitumen in Canada and oil shale in Venezuela. While significant volumes of oil are extracted from oil sands, particularly in Canada, logistical and technical hurdles remain, as oil extraction requires large amounts of heat and water, making its net energy content quite low relative to conventional crude oil. Thus, Canada's oil sands are not expected to provide more than a few million barrels per day in the foreseeable future.

Conventional crude oil production, those having Net Energy Gain above 10 stopped growing in 2005 at about 74 million barrels per day (11,800,000 m^3/d). The International Energy Agency's (IEA) 2010 World Energy Outlook estimated that conventional crude oil production has peaked and is depleting at 6.8 percent per year. US Joint Forces Command's Joint Operating Environment 2010 issued this warning to all US military commands "By 2012, surplus oil production capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 million barrels per day."

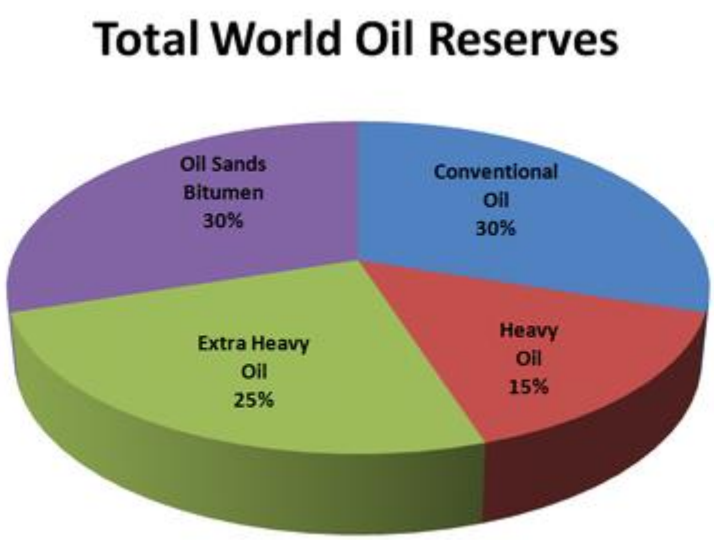
2.2.2.2 **Composition**

In its strictest sense, petroleum includes only crude oil, but in common usage it includes all liquid, gaseous, and solid hydrocarbons. Under surface pressure and temperature conditions, lighter hydrocarbon methane, ethane, propane and butane occur as gases, while pentane and heavier ones are in the form of liquids or solids. However, in an underground oil reservoir the proportions of gas, liquid, and solid depend on subsurface conditions and on the phase diagram of the petroleum mixture.

An oil well produces predominantly crude oil, with some natural gas dissolved in it. Because the pressure is lower at the surface than underground, some of the gas will come out of solution and be recovered (or burned) as *associated gas* or *solution gas*. A gas well produces predominantly natural gas. However, because the underground temperature and pressure are higher than at the surface, the gas may contain heavier hydrocarbons such as pentane, hexane, and heptane in the gaseous state. At surface conditions these will condense out of the gas to form a natural gas condensate, often shortened to *condensate.* Condensate resembles petrol in appearance and is similar in composition to some volatile light crude oils.

The proportion of light hydrocarbons in the petroleum mixture varies greatly among different oil fields, ranging from as much as 97 percent by weight in the lighter oils to as little as 50 percent in the heavier oils and bitumens.

The hydrocarbons in crude oil are mostly alkanes, cycloalkanes and various aromatic hydrocarbons while the other organic compounds contain nitrogen, oxygen and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium. The exact molecular composition varies widely from formation to formation but the proportion of chemical elements vary over fairly narrow limits as follows:



Most of the world's oil is non-conventional.

Composition by weight

Element	Percent range
Carbon	83 to 85%
Hydrogen	10 to 14%
Nitrogen	0.1 to 2%
Oxygen	0.05 to 1.5%
Sulfur	0.05 to 6.0%
Metals	< 0.1%

Four different types of hydrocarbon molecules appear in crude oil. The relative percentage of each varies from oil to oil, determining the properties of each oil.

	Composition by weight	
Hydrocarbon	**Average**	**Range**
Alkanes (paraffins)	30%	15 to 60%
Naphthenes	49%	30 to 60%
Aromatic	15%	3 to 30%
Asphalts	6%	Remainder

Crude oil varies greatly in appearance depending on its composition. It is usually black or dark brown (although it may be yellowish, reddish, or even greenish). In the reservoir it is usually found in association with natural gas, which being lighter forms a gas cap over the petroleum, and saline water which, being heavier than most forms of crude oil, generally sinks beneath it. Crude oil may also be found in semi-solid form mixed with sand and water, as in the Athabasca oil sands in Canada, where it is usually referred to as crude bitumen. In Canada, bitumen is considered a sticky, black, tar-like form of crude oil which is so thick and heavy that it must be heated or diluted before it will flow. Venezuela also has large amounts of oil in the Orinoco oil sands, although the hydrocarbons trapped in them are more fluid than in Canada and are usually called extra heavy oil. These oil sands resources are called unconventional oil to distinguish them from oil which can be extracted using traditional oil well methods. Between them, Canada and Venezuela contain an estimated 3.6 trillion barrels (570×10^9 m^3) of bitumen and extra-heavy oil, about twice the volume of the world's reserves of conventional oil.

Petroleum is used mostly, by volume, for producing fuel oil and petrol, both important *"primary energy"* sources. 84 percent by volume of the hydrocarbons present in petroleum is converted into energy-rich fuels (petroleum-based fuels), including petrol, diesel, jet, heating, and other fuel oils, and liquefied petroleum gas. The lighter grades of crude oil produce the best yields of these products, but as the world's reserves of light and medium oil are depleted, oil refineries are using more complex and expensive methods to produce the products required. Because heavier crude oils have too much carbon and not enough hydrogen, these processes generally involve removing carbon from or adding hydrogen to the molecules, and using fluid catalytic cracking to convert the longer, more complex molecules in the oil to the shorter, simpler ones in the fuels.

Due to its high energy density, easy transportability and relative abundance, oil have become the world's most important source of energy since the mid-1950s. Petroleum is also the raw material for many chemical products, including pharmaceuticals, solvents, fertilizers, pesticides, and plastics; the 16 percent not used for energy production is converted into these other materials. Petroleum is found in porous rock formations in the upper strata of some areas of the Earth's crust. There is also petroleum in oil sands (tar sands). Known oil reserves are typically estimated at around 190 km^3 (1.2 trillion (short scale) barrels) without oil sands, or 595 km^3 (3.74 trillion barrels) with oil sands. Consumption is currently around 84 million barrels (13.4×10 m) per day, or 4.9 km^3 per year. Which in turn yields a remaining oil supply of only about 120 years, if current demand remains static.

2.2.2.3 **Chemistry**

Petroleum is a mixture of a very large number of different hydrocarbons; the most commonly found molecules are alkanes (paraffins), cycloalkanes (naphthenes), aromatic hydrocarbons, or more complicated chemicals like asphaltenes. Each petroleum variety has a unique mix of molecules, which define its physical and chemical properties, like color and viscosity.

The *alkanes*, also known as *paraffins*, are saturated hydrocarbons with straight or branched chains which contain only carbon and hydrogen and have the general formula C_nH_{2n+2}. They generally have from 5 to 40 carbon atoms per molecule, although trace amounts of shorter or longer molecules may be present in the mixture.

The alkanes from pentane (C_5H_{12}) to octane (C_8H_{18}) are refined into petrol, the ones from nonane (C_9H_{20}) to hexadecane ($C_{16}H_{34}$) into diesel fuel, kerosene and jet fuel. Alkanes with more than 16 carbon atoms can be refined into fuel oil and lubricating oil. At the heavier end of the range, paraffin wax is an alkane with approximately 25 carbon atoms, while asphalt has 35 and up, although these are usually cracked by modern refineries into more valuable products. The shortest molecules, those with four or fewer carbon atoms, are in a gaseous state at room temperature. They are the petroleum gases. Depending on demand and the cost of recovery, these gases are either flared off, sold as liquified petroleum gas under pressure, or used to power the refinery's own burners. During the winter, butane (C_4H_{10}), is blended into the petrol pool at high rates, because its high vapor pressure assists with cold starts. Liquified under pressure slightly above atmospheric, it is best known for powering cigarette lighters, but it is also a main fuel source for many developing countries. Propane can be liquified under modest pressure, and is consumed for just about every application relying on petroleum for energy, from cooking to heating to transportation.

The *cycloalkanes*, also known as *naphthenes*, are saturated hydrocarbons which have one or more carbon rings to which hydrogen atoms are attached according to the formula C_nH_{2n}. Cycloalkanes have similar properties to alkanes but have higher boiling points.

The *aromatic hydrocarbons* are unsaturated hydrocarbons which have one or more planar six-carbon rings called benzene rings, to which hydrogen atoms are attached with the formula C_nH_n. They tend to burn with a sooty flame, and many have a sweet aroma. Some are carcinogenic.

These different molecules are separated by fractional distillation at an oil refinery to produce petrol, jet fuel, kerosene, and other hydrocarbons. For example, 2,2,4-trimethylpentane (isooctane), widely used in petrol, has a chemical formula of C8H18 and it reacts with oxygen exothermically.

2 C
8H
$18_{(l)}$ + 25 O
$2_{(g)}$ → 16 CO
$2_{(g)}$ + 18 H
$2O_{(g)}$ (ΔH = −10.86 MJ/mol of octane)

The amount of various molecules in an oil sample can be determined in laboratory. The molecules are typically extracted in a solvent, then separated in a gas chromatograph, and finally determined with a suitable detector, such as a flame ionization detector or a mass spectrometer. Due to the large number of co-eluted hydrocarbons within oil, many cannot be resolved by traditional gas chromatography and typically appear as a hump in the chromatogram. This unresolved complex mixture (UCM) of hydrocarbons is particularly apparent when analyzing weathered oils and extracts from tissues of organisms exposed to oil.

Incomplete combustion of petroleum or petrol results in production of toxic byproducts. Too little oxygen results in carbon monoxide. Due to the high temperatures and high pressures involved, exhaust gases from petrol combustion in car engines usually include nitrogen oxides which are responsible for the creation of photochemical smog.

2.2.2.4 **Formation**

Petroleum is a fossil fuel derived from ancient fossilized organic materials, such as zooplankton and algae. Vast quantities of these remains settled to a sea or lake bottoms, mixing with sediments and being buried under anoxic conditions. As further layers settled to the sea or lake bed, intense heat and pressure built up in the lower regions. This process caused the organic matter to change, first into a waxy material known as kerogen, which is found in various oil shales around the world, and then with more heat into liquid and gaseous hydrocarbons via a process known as catagenesis. Formation of petroleum occurs from hydrocarbon pyrolysis in a variety of mainly endothermic reactions at high temperature and/or pressure.

There were certain warm nutrient-rich environments such as the Gulf of Mexico and the ancient Tethys Sea where the large amounts of organic material falling to the ocean floor exceeded the rate at which it could decompose. This resulted in large masses of organic material being buried under subsequent deposits such as shale formed from mud. This massive organic deposit later became heated and transformed under pressure into oil.

Geologists often refer to the temperature range in which oil forms as an "oil window"—below the minimum temperature oil remains trapped in the form of kerogen, and above the maximum temperature the oil is converted to natural gas through the process of thermal cracking. Sometimes, oil formed at extreme depths may migrate and become trapped at a much shallower level. The Athabasca Oil Sands are one example of this.

An alternative mechanism was proposed by Russian scientists in the mid-1850s, the Abiogenic petroleum origin, but it's still a hypothesis.

2.2.2.5 Reservoirs

2.2.2.5.1 Crude oil reservoirs

Three conditions must be present for oil reservoirs to form: a source rock rich in hydrocarbon material buried deep enough for subterranean heat to cook it into oil; a porous and permeable reservoir rock for it to accumulate in; and a cap rock (seal) or other mechanism that prevents it from escaping to the surface. Within these reservoirs, fluids will typically organize themselves like a three-layer cake with a layer of water below the oil layer and a layer of gas above it, although the different layers vary in size between reservoirs. Because most hydrocarbons are less dense than rock or water, they often migrate upward through adjacent rock layers until either reaching the surface or becoming trapped within porous rocks (known as reservoirs) by impermeable rocks above. However, the process is influenced by underground water flows, causing oil to migrate hundreds of kilometers horizontally or even short distances downward before becoming trapped in a reservoir. When hydrocarbons are concentrated in a trap, an oil field forms, from which the liquid can be extracted by drilling and pumping.

The reactions that produce oil and natural gas are often modeled as first order breakdown reactions, where hydrocarbons are broken down to oil and natural gas by a set of parallel reactions, and oil eventually breaks down to natural gas by another set of reactions. The latter set is regularly used in petrochemical plants and oil refineries.

Wells are drilled into oil reservoirs to extract the crude oil. "Natural lift" production methods that rely on the natural reservoir pressure to force the oil to the surface are usually sufficient for a while after reservoirs are first tapped. In some reservoirs, such as in the Middle East, the natural pressure is sufficient over a long time. The natural pressure in most reservoirs, however, eventually dissipates. Then the oil must be extracted using "artificial lift" means. Over time, these "primary" methods become less effective and "secondary" production methods may be used. A common secondary method is "water flood" or injection of water into the reservoir to increase pressure and force the oil to the drilled shaft or "wellbore." Eventually "tertiary" or "enhanced" oil recovery methods may be used to increase the oil's flow characteristics by injecting steam, carbon dioxide and other gases or chemicals into the reservoir. In the United States, primary production methods account for less than 40 percent of the oil produced on a daily basis, secondary methods account for about half, and tertiary recovery the remaining 10 percent. Extracting oil (or "bitumen") from oil/tar sand and oil shale deposits requires mining the sand or shale and heating it in a vessel or retort, or using "in-situ" methods of injecting heated liquids into the deposit and then pumping out the oil-saturated liquid.

2.2.2.5.2 **Unconventional oil reservoirs**

Oil-eating bacteria biodegrade oil that has escaped to the surface. Oil sands are reservoirs of partially biodegraded oil still in the process of escaping and being biodegraded, but they contain so much migrating oil that, although most of it has escaped, vast amounts are still present—more than can be found in conventional oil reservoirs. The lighter fractions of the crude oil are destroyed first, resulting in reservoirs containing an extremely heavy form of crude oil, called crude bitumen in Canada, or extra-heavy crude oil in Venezuela. These two countries have the world's largest deposits of oil sands.

On the other hand, oil shales are source rocks that have not been exposed to heat or pressure long enough to convert their trapped hydrocarbons into crude oil. Technically speaking, oil shales are not always shales and do not contain oil, but are fine-grain sedimentary rocks containing an insoluble organic solid called kerogen. The kerogen in the rock can be converted into crude oil using heat and pressure to simulate natural processes. The method has been known for centuries and was patented in 1694 under British Crown Patent No. 330 covering, "A way to extract and make great quantities of pitch, tar, and oil out of a sort of stone." Although oil shales are found in many countries, the United States has the world's largest deposits.

2.2.2.6 **Categorization**

The petroleum industry generally classifies crude oil by the geographic place it is produced in (e.g. West Texas Intermediate, Brent, or Oman), its API gravity (an oil industry measure of density), and its sulfur content. Crude oil may be considered *light* if it has low density or *heavy* if it has high density; and it may be referred to as sweet if it contains relatively little sulfur or *sour* if it contains substantial amounts of sulfur.

The geographic place is important because it affects transportation costs to the refinery. *Light* crude oil is more desirable than *heavy* oil since it produces a higher yield of petrol, while *sweet* oil commands a higher price than *sour* oil because it has fewer environmental problems and requires less refining to meet sulfur standards imposed on fuels in consuming countries. Each crude oil has unique molecular characteristics which are understood by the use of crude oil assay study in petroleum laboratories.

Barrels from an area in which the crude oil's molecular characteristics have been determined and the oil has been classified are used as pricing references throughout the world. Some of the common reference crudes are:

- West Texas Intermediate (WTI), a very high-quality, sweet, light oil delivered at Cushing, Oklahoma for North American oil
- Brent Blend, comprising 15 oils from fields in the Brent and Ninian systems in the East Shetland Basin of the North Sea. The oil is landed at Sullom Voe terminal in Shetland. Oil production from Europe, Africa and Middle Eastern oil flowing West tends to be priced off this oil, which forms a benchmark
- Dubai-Oman, used as benchmark for Middle East sour crude oil flowing to the Asia-Pacific region
- Tapis (from Malaysia, used as a reference for light Far East oil)
- Minas (from Indonesia, used as a reference for heavy Far East oil)
- The OPEC Reference Basket, a weighted average of oil blends from various OPEC (The Organization of the Petroleum Exporting Countries) countries
- Midway Sunset Heavy, by which heavy oil in California is priced

There are declining amounts of these benchmark oils being produced each year, so other oils are more commonly what is actually delivered. While the reference price may be for West Texas Intermediate delivered at Cushing, the actual oil being traded may be a discounted Canadian heavy oil delivered at Hardisty, Alberta, and for a Brent Blend delivered at Shetland, it may be a Russian Export Blend delivered at the port of Primorsk.

2.2.2.7 **Petroleum industry**

The petroleum industry is involved in the global processes of exploration, extraction, refining, transporting (often with oil tankers and pipelines), and marketing petroleum products. The largest volume products of the industry are fuel oil and petrol. Petroleum is also the raw material for many chemical products, including pharmaceuticals, solvents, fertilizers, pesticides, and plastics. The industry is usually divided into three major components: upstream, midstream and downstream. Midstream operations are usually included in the downstream category.

Petroleum is vital to many industries, and is of importance to the maintenance of industrialized civilization itself, and this is a critical concern to many nations. Oil accounts for a large percentage of the world's energy consumption, ranging from a low of 32 percent for Europe and Asia, up to a high of 53 percent in the Middle East, South and Central America (44%), Africa (41%), and North America (40%). The world at large consumes 30 billion barrels (4.8 km^3) of oil per year, and the top oil consumers largely consist of developed nations. In fact, 24 percent of the oil consumed in 2004 went to the United States alone, though by 2007 this had dropped to 21 percent of world oil consumed.

In the US, in the states of Arizona, California, Hawaii, Nevada, Oregon and Washington, the Western States Petroleum Association (WSPA) represents companies responsible for producing, distributing, refining, transporting and marketing petroleum. This non-profit trade association was founded in 1907, and is the oldest petroleum trade association in the United States.

2.2.3 **Hydro Electricity**

Hydropower

Hydropower or **water-power** is power derived from the energy of falling water and running water, which may be harnessed for useful purposes. Kinetic energy of flowing water (when it moves from higher potential to lower potential) rotates the blades/propellers of the turbine, which rotates the axle. The axle has a coil which is placed between the magnets. When the coils rotate in magnetic field it induces them in the coil due to change in flux. Hence, kinetic energy of flowing water is converted to electrical energy.

Since ancient times, water-power has been used for irrigation and the operation of various mechanical devices, such as watermills, sawmills, textile mills, dock cranes, domestic lifts, power houses and paint making.

Since the early 20th century, the term has been used almost exclusively in conjunction with the modern development of hydroelectric power, which allowed use of distant energy sources. Another method used to transmit energy used a trompe, which produces compressed air from falling water. Compressed air could then be piped to power other machinery at a distance from the waterfall. Hydro power is a renewable energy source.

The water's power is manifested in hydrology, by the forces of water on the riverbed and banks of a river. When a river is in flood, it is at its most powerful, and moves the greatest amount of sediment. This higher force resulting in the removal of sediment and other material from the riverbed and banks of the river, locally causing erosion, transport and, with lower flow, sedimentation downstream.

2.2.3.1 History

Early uses of water power date back to Mesopotamia and ancient Egypt, where irrigation has been used since the 4th millennium BC and water clocks had been used since the early 2nd millennium BC. Other early examples of water power include the Qanat system in ancient Persia and the Turpan water system in ancient China. Water clocks had been used since the early 2nd millennium BC.

2.2.3.2 Waterwheels, turbines, and mills

In India, water wheels and watermills were built; in Imperial Rome, water powered mills produced flour from grain, and were also used for sawing timber and stone; in China, watermills were widely used since the Han Dynasty. In China and the rest of the Far East, hydraulically operated "pot wheel" pumps raised water into irrigation canals.

In 1753, French engineer Bernard Forest de Bélidor published *Architecture Hydraulique* which described vertical- and horizontal-axis hydraulic machines. By the late 19th century, the electrical generator was developed and could now be coupled with hydraulics. The growing demand for the Industrial Revolution would drive development as well.

The power of a wave of water released from a tank was used for extraction of metal ores in a method known as hushing. The method was first used at the Dolaucothi gold mine in Wales from 75 AD onwards, but had been developed in Spain at such mines as Las Medulas. Hushing was also widely used in Britain in the Medieval and later periods to extract lead and tin ores. It later evolved into hydraulic mining when used during the California gold rush.

At the beginning of the Industrial revolution in Britain, water was the main source of power for new inventions such as Richard Arkwright's water frame. Although the use of water power gave way to steam power in many of the larger mills and factories, it was still used during the 18th and 19th centuries for many smaller operations, such as driving the bellows in small blast furnaces (e.g. The Dyfi Furnace) and grist mills, such as those built at Saint Anthony Falls, which uses the 50-foot (15 m) drop in the Mississippi River.

In the 1830s, at the early peak in U.S. canal-building, hydropower provided the energy to transport barge traffic up and down steep hills using inclined plane railroads. As railroads obvious oak canals for transportation, canal systems were modified and developed into hydropower systems; the history of Lowell, Massachusetts is a classic example of commercial development and industrialization, built upon the availability of water power.

Technological advances had moved the open water wheel into an enclosed turbine. In 1848 James B. Francis, while working as head engineer of Lowell's Locks and Canals company, improved on these designs to create a turbine with 90% efficiency. He applied scientific principles and testing methods to the problem of turbine design. His mathematical and graphical calculation methods allowed confident design of high efficiency turbines to exactly match a site's specific flow conditions. The Francis reaction turbine is still in wide use today. In the 1870s, deriving from uses in the California mining industry, Lester Allan Pelton developed the high efficiency Pelton wheel impulse turbine, which utilized hydropower from the high head streams characteristic of the mountainous California interior.

2.2.3.2 Hydraulic power-pipe networks

Hydraulic power networks also developed, using pipes to carry pressurized water and transmit mechanical power from the source to end users elsewhere locally; the power source was normally a head of water, which could also be assisted by a pump. These were extensively in Victorian cities in the United Kingdom. A hydraulic power network was also developed in Geneva, Switzerland. The world famous Jet d'Eau was originally designed as the over-pressure relief valve for the network.

2.2.3.3 Compressed air hydro

Where there is a plentiful head of water it can be made to generate compressed air directly without moving parts. In these designs, a falling column of water is purposely mixed with air bubbles generated through turbulence in the high level intake. This allows to fall down a shaft into a subterranean, high-roofed chamber where the now-compressed air separates from the water and becomes trapped. The height of the falling water column maintains compression of the air in the top of the chamber, while an outlet, submerged below the water level in the chamber allows water to flow back to the surface at a slightly lower level than the intake. A separate outlet in the roof of the chamber supplies the compressed air to the surface. A facility on this principle was built on the Montreal River at Ragged Shutes near Cobalt, Ontario in 1910 and supplied 5,000 horsepower to nearby mines.

2.2.3.4 21st Century

Having fallen out of favor during the late 20th century due to the disruptive ecological and social effects of large impoundments, hydropower enjoyed a revival by 2013 as international institutions such as the World Bank tried to find solutions to economic development which avoided adding substantial amounts of carbon to the atmosphere.

Calculating the amount of available power

A hydropower resource can be evaluated by its available power. Power is a function of the hydraulic head and rate of fluid flow. The head is the energy per unit weight (or unit mass) of water. The static head is proportional to the difference in height through which the water falls. Dynamic head is related to the velocity of moving water. Each unit of water can do an amount of work equal to its weight times the head.

The power available from falling water can be calculated from the flow rate and density of water, the height of fall, and the local acceleration due to gravity. In SI units, the power is:

$$P = \eta \rho Q g h$$

Where

- P is power in watts
- η is the dimensionless efficiency of the turbine
- ρ is the density of water in kilograms per cubic meter
- Q is the flow in cubic metres per second
- g is the acceleration due to gravity
- h is the height difference between inlet and outlet

To illustrate, power is calculated for a turbine that is 85% efficient, with water at 62.25 pounds/cubic foot (998 kg/cubic meter) and a flow rate of 2800 cubic-feet/second (79.3 cubic-meters/second), gravity of 9.80 meters per second squared and with a net head of 480 ft (146.3 m).

In SI units:

$$\text{Power (MW)} = 0.85 \times \frac{998 \times 79.3 \times 9.80 \times 146.3}{1000000}$$ Which gives 96.4 MW

In English units, the density is given in pounds per cubic foot so the acceleration due to gravity is inherent in the unit of weight. A conversion factor is required to change from foot lbs/second to kilowatts:

$$\text{Power (MW)} = 0.85 \times \frac{62.25 \times 2800 \times 480}{(1000 \times 737.5)}$$ Which gives 96.4 MW

Operators of hydroelectric plants will compare the total electrical energy produced with the theoretical potential energy of the water passing through the turbine to calculate efficiency. Field testing of turbines is used to validate the manufacturer's guaranteed efficiency. Detailed calculation of the efficiency of a hydropower turbine will account for the head lost due to flow friction in the power canal or penstock, rise in tail water level due to flow, the place of the plant and effect of varying gravity, the temperature and barometric pressure of the air, the density of the water at ambient temperature, and the altitudes above sea level of the forebay and tailbay. In precise calculations, errors due to rounding and the number of significant digits of constants must be considered.

Some hydropower systems such as water wheels can draw power from the flow of a body of water without necessarily changing its height. In this case, the available power is the kinetic energy of the flowing water. Overshot water wheels can efficiently capture both types of energy.

The water flow in a stream can vary widely from season to season. Development of a hydropower site requires study of flow records, sometimes spanning decades, to assess the reliability annual energy supply. Dams and reservoirs provide a more dependable source of power by smoothing seasonal changes in water flow. However reservoirs have significant environmental impact, as does the alteration of natural occurring stream flow. The design of dams must also account for the worst-case, "probable maximum flood" that can be expected at the site; a spillway is often included to bypass flood flows around the dam.

A computer model of the hydraulic basin and rainfall and snowfall records are used to predict the maximum flood.

2.2.3.5 **Hydroelectricity**

2.2.3.1 **Hydroelectricity** is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity produced in 2010, and is expected to increase about 3.1% each year for the next 25 years.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectric producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now three hydroelectric plants larger than 10 GW: the Three Gorges Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela.

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro plant larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour. Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants.

2.2.3.5.1 History

Hydropower has been used since ancient times to grind flour and perform other tasks. In the mid-1770s, French engineer Bernard Forest de Bélidor published *Architecture Hydraulique* which described vertical- and horizontal-axis hydraulic machines. By the late 19th century, the electrical generator was developed and could now be coupled with hydraulics. The growing demand for the Industrial Revolution would drive development as well. In 1878 the world's first hydroelectric power scheme was developed at Cragside in Northumberland, England by William George Armstrong. It was used to power a single arc lamp in his art gallery. The old Schoelkopf Power Station No. 1 near Niagara Falls in the U.S. side began to produce electricity in 1881. The first Edison hydroelectric power plant, the Vulcan Street Plant, began operating September 30, 1882, in Appleton, Wisconsin, with an output of about 12.5 kilowatts. By 1886 there were 45 hydroelectric power plants in the U.S. and Canada. By 1889 there were 200 in the U.S. alone.

At the beginning of the 20th century, many small hydroelectric power plants were being constructed by commercial companies in the mountains near metropolitan areas. Grenoble, France held the International Exhibition of Hydropower and Tourism with over one million visitors. By 1920 as 40% of the power produced in the United States was hydroelectric, the Federal Power Act was enacted into law. The Act created the Federal Power Commission to regulate hydroelectric power plants on federal land and water. As the power plants became larger, their associated dams developed additional purposes to include flood control, irrigation and navigation. Federal funding became necessary for large-scale development and federally owned corporations, such as the Tennessee Valley Authority (1933) and the Bonneville Power Administration (1937) were created. Additionally, the Bureau of Reclamation which had began a series of western U.S. irrigation projects in the early 20th century was now constructing large hydroelectric projects such as the 1928 Hoover Dam. The U.S. Army Corps of Engineers was also involved in hydroelectric development, completing the Bonneville Dam in 1937 and being recognized by the Flood Control Act of 1936 as the premier federal flood control agency.

Hydroelectric power plants continued to become larger throughout the 20th century. Hydropower was referred to as *white coal* for its power and plenty. Hoover Dam's initial 1,345 MW power plant was the world's largest hydroelectric power plant in 1936; it was eclipsed by the 6809 MW Grand Coulee Dam in 1942. The Itaipu Dam opened in 1984 in South America as the largest, producing 14,000 MW but was surpassed in 2008 by the Three Gorges Dam in China at 22,500 MW. Hydroelectricity would eventually supply some countries, including Norway, Democratic Republic of the Congo, Paraguay and Brazil, with over 85% of their electricity. The United States currently has over 2,000 hydroelectric power plants that supply 6.4% of its total electrical production output, which is 49% of its renewable electricity.

2.2.3.5.2 Generating methods

2.2.3.5.2.1 Conventional (dams)

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head. A large pipe (the "penstock") delivers water to the turbine.

2.2.3.5.2.2 Pumped-storage

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine. Pumped-storage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system. Pumped storage is not an energy source, and appears as a negative number in the listings.

2.2.3.5.2.3 Run-of-the-river

Run-of-the-river hydroelectric stations are those with small or no reservoir capacity, so that the water coming from upstream must be used for generation at that moment, or must be allowed to bypass the dam. In the United States, run of the river hydropower could potentially provide 60,000 MW (about 13.7% of total use in 2011 if continuously available).

2.2.3.5.2.4 Tide

A tidal power plant makes use of the daily rise and fall of ocean water due to tides; such sources are highly predictable, and if conditions permit construction of reservoirs, can also be dispatchable to generate power during high demand periods. Less common types of hydro schemes use water's kinetic energy or undammed sources such as undershot waterwheels. Tidal power is viable in a relatively small number of places around the world. In Great Britain, there are eight sites that could be developed, which have the potential to generate 20% of the electricity used in 2012.

2.2.3.5.2.5 Underground

An underground power station makes use of a large natural height difference between two waterways, such as a waterfall or a mountain lake. An underground tunnel is constructed to take water from the high reservoir to the generating hall built in an underground cavern near the lowest point of the water tunnel and a horizontal tailrace taking water away to the lower outlet waterway.

2.3 Resource Conservation

Natural resource management refers to the management of natural resources such as land, water, land, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations (stewardship).

Natural resource management deals with managing the way in which people and natural landscapes interact. It brings together land use planning, water management, biodiversity Protection, and the future sustainability of industries like agriculture, mining, tourism, fisheries and forestry. It recognizes that people and their livelihoods rely on the health and productivity of our landscapes, and their actions as stewards of the land play a critical role in maintaining this health and productivity.

Natural resource management is also congruent with the idea of sustainable development, a scientific principle that forms a basis for sustainable global land management and environmental governance to conserve and preserve natural resources.

Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources. Environmental management is also similar to natural resource management. In academic contexts, the sociology of natural resources is closely related to, but distinct from, natural resource management.

2.3.1 **History**

The emphasis on sustainability can be traced back to early attempts to understand the ecological nature of North American rangelands in the late 19th century, and the resource Protection movement of the same time. This type of study coalesced in the 20th century with the recognition that preservationist Protection strategies had not been effective in halting the decline of natural resources. A more integrated approach was implemented recognizing the intertwined social, cultural, economic and political aspects of resource management. A more holistic, national and even global form evolved, from the Brundtland Commission and the advocacy of sustainable development.

In 2005 the government of New South Wales, established a *Standard for Quality Natural Resource Management*, to improve the consistency of practice, based on an adaptive management approach.

In the United States, the most active areas of natural resource management are wildlife management often associated with eco-tourism and rangeland (pastures) management. In Australia, water sharing, such as the Murray Darling Basin Plan and catchment management are also significant.

2.3.2 Ownership regimes

Natural resource management approaches can be categorized according to the kind and right of stakeholders, natural resources:

- State property

- Private property
- Common property
- Non-property (open access)
- Hybrid

2.3.2.1 State Property Regime

Ownership and control over the use of resources is in the hands of the state. Individuals or groups may be able to make use of the resources, but only at the permission of the state. National forest, National parks and military reservations are some US examples..

2.3.2.2 Private Property Regime

Any property owned by a defined individual or corporate entity. Both the benefit and duties to the resources fall to the owner(s). Private land is the most common example.

2.3.2.3 Common Property Regimes

It is a private property of a group. The group may vary in size, nature and internal structure e.g. Indigenous tribe, neighbors of village. Some examples of common property are community forests and water resources.

2.3.2.4 Non-property Regimes (open access)

There is no definite owner of these properties. Each potential user has equal ability to use it as they wish. These areas are the most exploited. It is said that "Everybody's property is nobody's property". An example is a lake fishery. This ownership regime is often linked to the tragedy of the commons.

2.3.2.5 Hybrid Regimes

Many ownership regimes governing natural resources will contain parts of more than one of the regimes described above, so natural resource managers need to consider the impact of hybrid regimes. An example of such a hybrid is native vegetation management in NSW, Australia, where legislation recognizes a public interest in the preservation of native vegetation, but where most native vegetation exists on private land.

2.3.3 Stakeholder study

Stakeholder study originated from business management practices and has been incorporated into natural resource management in ever growing popularity. Stakeholder study in the context of natural resource management identifies distinctive interest groups affected in the utilization and Protection of natural resources.

There is no definitive definition of a stakeholder as illustrated in the table below. Especially in natural resource management as it is difficult to determine who has a stake and this will differ according to each potential stakeholder.

2.3.4 Different approaches to who is a stakeholder:

Source	Who is a stakeholder	Kind of research
Freeman.	‘‘Can affect or is affected by the achievement of the organization’s objectives’’	Business Management
Bowie	‘‘Without whose support the organization would cease to exist’’	Business Management
Clarkson	‘‘...Persons or groups that have, or claim, ownership, rights, or interests in a corporation and its actions , past, present, or future.’’	Business Management
Grimble and Wellard	‘‘...Any group of people, organized or unorganized, who share a common interest or stake in a particular issue or system...’’	Natural resource management
Gass et al.	‘‘...any individual, group and institution who would potentially be affected, whether positively or negatively, by a specified event, process or change.’’	Natural resource management
Buanes et al	‘‘...any group or individual who may directly or indirectly affect—or be affected—...planning to be at least potential stakeholders.’’	Natural resource management
Brugha and Varvasovszky	‘‘...actors who have an interest in the issue under consideration, who are affected by the issue, or who—because of their position—have or could have an active or passive influence on the decision making and implementation process.’’	Health policy
ODA	‘‘... persons, groups or institutions with interests in a project or programme.’’	Development

Therefore it is dependent upon the circumstances of the stakeholders involved with natural resource as to which definition and subsequent theory is utilised.

Billgrena and Holme identified the aims of stakeholder study in natural resource management:

- Identify and categorise the stakeholders that may have influence
- Develop an understanding of why changes occur
- Establish who can make changes happen
- How to best manage natural resources

This gives transparency and clarity to policy making allowing stakeholders to recognise conflicts of interest and facilitate resolutions. There are numerous stakeholder theories such as Mitchell et al. however Grimble created a framework of stages for a Stakeholder Study in natural resource management. Grimble designed this framework to ensure that the study is specific to the necessary aspects of natural resource management.

2.3.4 Stages in Stakeholder study :

1. Clarify objectives of the study
2. Place issues in a systems context

3. Identify decision-makers and stakeholders
4. Investigate stakeholder interests and agendas
5. Investigate patterns of interaction and dependence (e.g. conflicts and compatibilities, trade-offs and synergies)

Application:

Grimble and Wellard established that the Stakeholder study in natural resource management is most relevant where issued can be characterized as;

- Crosscutting systems and stakeholder interests
- Multiple uses and users of the resource.
- Market failure
- Subtractability and temporal trade-offs
- Unclear or open-access property rights
- Unthreaded products and services
- Obvious y and under-representation

2.3.5 Case studies:

In the case of the Bwindi Impenetrable National Park, a comprehensive stakeholder study would have been relevant and the Batwa people would have potentially been acknowledged as stakeholders preventing the loss of people's livelihoods and loss of life.

Nepal, Indonesia and Koreas' community forestry are successful examples of how stakeholder study can be incorporated into the management of natural resources. This allowed the stakeholders to identify their needs and level of involvement with the forests.

2.3.6 Criticisms:

- Natural resource management stakeholder study tends to include too many stakeholders which can create problems in its self as suggested by Clarkson. ''Stakeholder theory should not be used to weave a basket big enough to hold the world's misery.''

- Strike proposed that nature needs to be represented as stakeholder. However this has been rejected by many scholars as it would be difficult to find appropriate representation and this representation could also be disputed by other stakeholders causing further issues.

- Stakeholder study can be used exploited and abused in order to marginalize other stakeholders.

- Identifying the relevant stakeholders for participatory processes is complex as certain stakeholder groups may have been excluded from previous decisions.

- On-going conflicts and lack of trust between stakeholders can prevent compromise and resolutions.

2.3.7 Alternatives/ Complementary forms of study :

- Social Network Study

- Common Pool Resource

2.3.8 Management approaches

Natural resource management issues are inherently complex as they involve the ecological cycles, hydrological cycles, climate, animals, plants and geography etc. All these are dynamic and interrelated. A change in one of them may have far reaching and/or long term impacts which may even be irreversible. In addition to the natural systems, natural resource management also has to manage various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and the list go on. It is very difficult to satisfy all aspects at the same time. This results in conflicting situations.

After the United Nations Conference for the Environment and Development (UNCED) held in Rio de Janeiro in 1992, most nations subscribed to new principles for the integrated management of land, water, and forests. Although program names vary from nation to nation, all express similar aims.

The various approaches applied to natural resource management include:

- Top-down or Command and control
- Bottom-up (regional or community based NRM)
- Adaptive management
- Precautionary approach
- Integrated approach (INRM)

2.3.8.1 Regional or Community Based NRM

The community based NRM approach combines Protection objectives with the generation of economic benefits for rural communities. The three key assumptions being that: locals are better placed to conserve natural resources, people will conserve a resource only if the benefits exceed the costs of Protection, and people will conserve a resource that is linked directly to their quality of life. When a local people's quality of life is enhanced, their efforts and commitment to ensure the future well-being of the resource are also enhanced. Regional and community based natural resource management is also based on the principle of subsidiarity.

The United Nations advocates community based NRM in the Convention on Biodiversity and the Convention to Combat Desertification. Unless clearly defined, decentralized NRM can result an ambiguous socio-legal environment with local communities racing to exploit natural resources while they can e.g. forest communities in central Kalimantan (Indonesia).

A problem of community based NRM is the difficulty of reconciling and harmonizing the objectives of socioeconomic development, biodiversity protection and sustainable resource utilization. The idea and conflicting interests of community based NRM, show how the motives behind the participation are differentiated as either people-centered (active or participatory results that are truly empowering) or planner-centered (nominal and results in passive recipients). Understanding power relations are crucial to the success of community based NRM. Locals may be reluctant to challenge government recommendations for fear of losing promised benefits.

Community based NRM is based particularly on advocacy by nongovernmental organizations working with local groups and communities, on the one hand, and national and transnational organizations, on the other, to build and extend new versions of environmental and social advocacy that link social justice and environmental management agendas with both direct and indirect benefits observed including a share of revenues, employment, diversification of livelihoods and increased pride and identity. CBNRM has raised new challenges, as ideas of community, territory, Protection, and indigenous are worked into politically varied plans and programs in disparate sites. Warner and Jones address strategies for effectively managing conflict in CBNRM.

The capacity of indigenous communities to conserve natural resources has been acknowledged by the Australian Government with the Caring for Country Program. Caring for our Country is an Australian Government initiative jointly administered by the Australian Government Department of Agriculture, Fisheries and Forestry and the Department of the Environment, Water, Heritage and the Arts. These Departments share responsibility for delivery of the Australian Government's environment and sustainable agriculture programs, which have traditionally been widely referred to under the banner of 'natural resource management'.

These programs have been delivered regionally, through 56 State government bodies, successfully allowing regional communities to decide the natural resource priorities for their regions.

Governance is seen as a key consideration for delivering community-based or regional natural resource management. In the State of NSW, the 13 catchment management authorities (CMAs) are overseen by the Natural Resources Commission (NRC), responsible for undertaking audits of the effectiveness of regional natural resource management programs.

2.3.8.2 Adaptive Management

The primary methodological approach adopted by catchment management authorities (CMAs) for regional natural resource management in Australia is adaptive management.

This approach includes recognition that adaption occurs through a process of 'plan-do-review-act'. It also recognizes seven key components that should be considered for quality natural resource management practice:

- Determination of scale
- Collection and use of knowledge
- Information management
- Monitoring and evaluation
- Risk management
- Community engagement
- Opportunities for collaboration.

2.3.8.3 Integrated natural resource management (INRM)

A process of managing natural resources in a systematic way, which includes multiple aspects of natural resource use (biophysical, socio-political, and economic) meet the production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental Protection). It focuses on sustainability and at the same time tries to incorporate all possible stakeholders from the planning level itself, reducing possible future conflicts. The idea of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management, and adaptive management. INRM is being used extensively and been successful in regional and community based natural management.

2.3.9 Frameworks and modelling

There are various frameworks and computer models developed to assist natural resource management.

2.3.10 Geographic Information Systems (GIS)

GIS is a powerful analytical tool as it is capable of overlaying datasets to identify links. A bush regeneration scheme can be informed by the overlay of rainfall, cleared land and erosion. In Australia, Metadata Directories such as NDAR provide data on Australian natural resources such as vegetation, fisheries, lands and water. These are limited by the potential for subjective input and data manipulation.

2.3.11 Natural Resources Management Audit Frameworks

The NSW Government in Australia has published an audit framework for natural resource management, to assist the establishment of a performance audit role in the governance of regional natural resource management. This audit framework builds from other established audit methodologies, including performance audit, environmental audit and internal audit. Audits undertaken using this framework have provided confidence to stakeholders, identified areas for improvement and described policy expectations for the general public.

The Australian Government has established a framework for auditing greenhouse emissions and energy reporting, which closely follows Australian Standards for Assurance Engagements.

The Australian Government is also currently preparing an audit framework for auditing water management, focussing on the implementation of the Murray Darling Basin Plan.

2.3.12 Other elements

The issue of biodiversity Protection is regarded as an important element in natural resource management. What is biodiversity? Biodiversity is a comprehensive idea , which is a description of the extent of natural diversity. Gaston and Spicer point out that biodiversity is "the variety of life" and relate to different kinds of "biodiversity organization". According to Gray, the first widespread use of the definition of biodiversity, was put forward by the United Nations in 1992, involving different aspects of biological diversity.

2.4 Principal Crops: Wheat, Rice, Sugarcane & Tea

2.4.1 Wheat

Wheat is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. In 2010, world production of wheat was 651 million tons, making it the third most-produced cereal after maize (844 million tons) and rice (672 million tons). Wheat was the second most-produced cereal in 2009; world production in that year was 682 million tons, after maize (817 million tons), and with rice as a close third (679 million tons).

This grain is grown on more land area than any other commercial food. World trade in wheat is greater than for all other crops combined. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, after allowing for maize's more extensive use in animal feeds.

Wheat was a key factor enabling the emergence of city-based societies at the start of civilization because it was one of the first crops that could be easily cultivated on a large scale, and had the additional advantage of yielding a harvest that provides long-term storage of food. Wheat contributed to the emergence of city-states in the Fertile Crescent, including the Babylonian and Assyrian empires. Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles, couscous and for fermentation to make beer, other alcoholic beverages, or biofuel.

Wheat is planted to a limited extent as a forage crop for livestock, and its straw can be used as a construction material for roofing thatch. The whole grain can be milled to leave just the endosperm for white flour. The by-products of this are bran and germ. The whole grain is a concentrated source of vitamins, minerals, and protein, while the refined grain is mostly starch.

2.4.1.1 History

Wheat is one of the first cereals known to have been domesticated, and wheat's ability to self-pollinate greatly facilitated the selection of many distinct domesticated varieties. The archaeological record suggests that this first occurred in the regions known as the Fertile Crescent. Recent findings narrow the first domestication of wheat down to a small region of southeastern Turkey, and domesticated Einkorn wheat at Nevalı Çori, 40 mi (64 km) northwest of Gobekli Tepe in Turkey—has been dated to 9,000 BCE. However evidence for the exploitation of wild barley has been dated to 23,000 BCE and some say this is also true of pre-domesticated wheat.

2.4.1.2 Origin

Cultivation and repeated harvesting and sowing of the grains of wild grasses led to the creation of domestic strains, as mutant forms ('sports') of wheat were preferentially chosen by farmers. In domesticated wheat, grains are larger, and the seeds (inside the spikelets) remain attached to the ear by a toughened rachis during harvesting. In wild strains, a more fragile rachis allows the ear to easily shatter and disperse the spikelets. Selection for these traits by farmers might not have been deliberately intended, but simply have occurred because these traits made gathering the seeds easier; nevertheless such 'incidental' selection was an important part of crop domestication. As the traits that improve wheat as a food source *also* involve the loss of the plant's natural seed dispersal mechanisms, highly domesticated strains of wheat cannot survive in the wild.

Cultivation of wheat began to spread beyond the Fertile Crescent after about 8000 BCE. Jared Diamond traces the spread of cultivated emmer wheat starting in the Fertile Crescent about 8500 BCE. Archaeological study of wild *emmer* indicates that it was first cultivated in the southern Levant with finds at Iran dating back as far as 9600 BCE. Genetic study of wild *einkorn* wheat suggests that it was first grown in the Karacadag Mountains in southeastern Turkey. Dated archeological remains of einkorn wheat in settlement sites near this region, including those at Abu Hureyra in Syria, suggest the domestication of einkorn near the Karacadag Mountain Range. With the anomalous exception of two grains from Iraq ed-Dubb, the earliest carbon-14 date for einkorn wheat remains at Abu Hureyra is 7800 to 7500 years BCE.

The remains of harvested emmer from several sites near the Karacadag Range have been dated to between 8600 (at Cayonu) and 8400 BCE (Abu Hureyra), that is, in the Neolithic period. With the exception of

Iraq ed-Dubb, the earliest carbon-14 dated remains of domesticated emmer wheat were found in the earliest levels of Tell Aswad, in the Damascus basin, near Mount Hermon in Syria. These remains were dated by Willem van Zeist and his assistant Johanna Bakker-Heeres to 8800 BCE. They also concluded that the settlers of Tell Aswad did not develop this form of emmer themselves, but brought the domesticated grains with them from an as yet unidentified place elsewhere.

The cultivation of emmer reached Greece, Cyprus and India by 6500 BCE, Egypt shortly after 6000 BCE, and Germany and Spain by 5000 BCE. "The early Egyptians were developers of bread and the use of the oven and developed baking into one of the first large-scale food production industries." By 3000 BCE, wheat had reached England and Scandinavia. A millennium later it reached China. The first identifiable bread wheat (*Triticum aestivum*) with sufficient gluten for yeasted breads has been identified using DNA study in samples from a granary dating to approximately 1350 BCE at Assiros in Greek Macedonia.

Wheat continued to spread throughout Europe. In England, wheat straw (thatch) was used for roofing in the Bronze Age, and was in common use until the late 19th century.

The State Emblem of the Soviet Union featured a wreath made of wheat.

2.4.1.3 Farming techniques

Technological advances in land preparation and seed placement at planting time, use of crop rotation and fertilizers to improve plant growth, and advances in harvesting methods have all combined to promote wheat as a viable crop. Agricultural cultivation using horse collar leveraged plows (at about 3000 BCE) was one of the first innovations that increased productivity. Much later, when the use of seed drills replaced webcasting sowing of seed in the 18th century, another great increase in productivity occurred.

Yields of pure wheat per unit area increased as methods of crop rotation were applied to long cultivated land, and the use of fertilizers became widespread. Improved agricultural husbandry has more recently included threshing machines and reaping machines (the 'combine harvester'), tractor-drawn cultivators and planters, and better varieties. The great expansion of wheat production occurred as new arable land was farmed in the Americas and Australia in the 19th and 20th centuries.

2.4.1.4 Genetics

Wheat genetics are more complicated than that of most other domesticated species. Some wheat species are diploid, with two sets of chromosomes, but many are stable polyploids, with four sets of chromosomes (tetraploid) or six (hexaploid).

- Einkorn wheat (*T. monococcum*) is diploid (AA, two complements of seven chromosomes, 2n=14).
- Most tetraploid wheats (e.g. emmer and durum wheat) are derived from wild emmer, *T. dicoccoides*. Wild emmer is itself the result of a hybridization between two diploid wild grasses, *T. urartu* and a wild goatgrass such as *Aegilops searsii* or *Ae. speltoides*. The unknown grass has never been identified among now surviving wild grasses, but the closest living relative is *Aegilops speltoides*. The hybridization that formed wild emmer (AABB) occurred in the wild, long before domestication, and was driven by natural selection.

- Hexaploid wheats evolved in farmers' fields. Either domesticated emmer or durum wheat hybridized with yet another wild diploid grass (*Aegilops tauschii*) to make the hexaploid wheats, spelt wheat and bread wheat. These have *three* sets of paired chromosomes, three times as many as in diploid wheat.

The presence of certain versions of wheat genes has been important for crop yields. Apart from mutant versions of genes selected in antiquity during domestication, there has been more recent deliberate selection of alleles that affect growth characteristics. Genes for the 'dwarfing' trait, first used by Japanese wheat breeders to produce short-stalked wheat, have had a huge effect on wheat yields world-wide, and were major factors in the success of the Green Revolution in Mexico and Asia. Dwarfing genes enable the carbon that is fixed in the plant during photosynthesis to be diverted towards seed production, and they also help prevent the problem of lodging. 'Lodging' occurs when an ear stalk falls over in the wind and rots on the ground, and heavy nitrogenous fertilization of wheat makes the grass grow taller and become more susceptible to this problem. By 1997, 81% of the developing world's wheat area was planted to semi-dwarf wheats, giving both increased yields and better response to nitrogenous fertilizer.

Wild grasses in the genus *Triticum* and related genera, and grasses such as rye have been a source of many disease-resistance traits for cultivating wheat breeding since the 1930s.

Heterosis, or hybrid vigor (as in the familiar F1 hybrids of maize), occurs in common (hexaploid) wheat, but it is difficult to produce seed of hybrid cultivars on a commercial scale (as is done with maize) because wheat flowers are perfect and normally self-pollinate. The commercial hybrid wheat seed has been produced using chemical hybridizing agents; these chemicals selectively interfere with pollen development, or naturally occurring cytoplasmic male sterility systems. Hybrid wheat has been a limited commercial success in Europe (particularly France), the USA and South Africa. F1 hybrid wheat cultivars should not be confused with the standard method of breeding inbred wheat cultivars by crossing two lines using hand emasculation, then selling or inbreeding the progeny many (ten or more) generations before release selections are identified to be released as a variety or cultivar.

Synthetic hexaploids made by crossing the wild goatgrass wheat ancestor *Aegilops tauschii* and various durum wheats are now being deployed, and these increases the genetic diversity of cultivated wheats.

Stomata (or leaf pores) are involved in both uptake of carbon dioxide gas from the atmosphere and water vapor losses from the leaf due to water transpiration. Basic physiological investigation of these gas exchange processes has yielded valuable carbon isotope based methods that are used for breeding wheat varieties with improved water-use efficiency. These varieties can improve crop productivity in rain-fed dry-land wheat farms.

In 2010, a team of UK scientists funded by BBSRC announced they had decoded the wheat genome for the first time (95% of the genome of a variety of wheat known as Chinese Spring line 42). This genome was released in a basic format for scientists and plant breeders to use but was not a fully annotated sequence which was reported in some of the media.

On 29 November 2012, whole-genome sequence of bread wheat has been published. Random shotgun libraries of total DNA and cDNA from the *T. aestivum* cv. Chinese Spring (CS42) were sequenced in Roche 454 pyrosequencer using GS FLX Titanium and GS FLX+ platforms to generate 85 GB of sequence (220 million reads), equivalent to 5X genome coverage and identified between 94,000 and 96,000 genes.

The wheat whole genome sequence data provide direct access to all 96,000 genes and represents a necessary step towards a systematic understanding of biology and engineering the cereal crop for valuable traits. Its implications in cereal genetics and breeding includes the examination of genome variation, association mapping using natural populations, performing wide crosses and alien introgression, studying the expression and nucleotide polymorphism in transcriptomes, analyzing population genetics and evolutionary biology, and studying the epigenetic modifications. Moreover, the availability of large-scale genetic markers generated through NGS technology will facilitate trait mapping and make marker-assisted breeding much feasible.

Moreover, the WGS data not only facilitate in deciphering the complex phenomenon such as heterosis and epigenetics, it may also enable breeders to predict which fragment of a chromosome is derived from which parent in the progeny line, thereby recognizing crossover events occurring in every progeny line and inserting markers on genetic and physical maps without ambiguity. In due course, this will assist in introducing specific chromosomal segments from one cultivar to another. Besides, the researchers had identified diverse classes of genes participating in energy production, metabolism and growth that were probably linked with crop yield, which can now be utilized for the development of transgenic wheat. Thus the whole genome sequence of wheat and the availability of thousands of SNPs will inevitably permit the breeders to stride towards identifying novel traits, providing biological knowledge and empowering biodiversity-based breeding.

2.4.1.5 Plant breeding

In traditional agricultural systems wheat populations often consist of landraces, informal farmer-maintained populations that often maintain high levels of morphological diversity. Although landraces of wheat are no longer grown in Europe and North America, they continue to be important elsewhere. The origins of formal wheat breeding lie in the nineteenth century, when single line varieties were created through the selection of seed from a single plant noted to have desired properties. Modern wheat breeding developed in the first years of the twentieth century and was closely linked to the development of Mendelian genetics. The standard method of breeding inbred wheat cultivars is by crossing two lines using hand emasculation, then selling or inbreeding the progeny. Selections are *identified* (shown to have the genes responsible for the varietal differences) ten or more generations before release as a variety or cultivar.

F1 hybrid wheat cultivars should not be confused with wheat cultivars deriving from standard plant breeding. Heterosis or hybrid vigor (as in the familiar F1 hybrids of maize) occurs in common (hexaploid) wheat, but it is difficult to produce seed of hybrid cultivars on a commercial scale as is done with maize because wheat flowers are complete and normally self-pollinate. The commercial hybrid wheat seed has been produced using chemical hybridizing agents, plant growth regulators that selectively interfere with pollen development, or naturally occurring cytoplasmic male sterility systems. Hybrid wheat has been a limited commercial success in Europe (particularly France), the United States and South Africa.

The major breeding objectives include high grain yield, good quality, disease and insect resistance and tolerance to abiotic stresses include mineral, moisture and heat tolerance. The major diseases in temperate environments include the following, arranged in a rough order of their significance from cooler to warmer climates: eyespot, Stagonospora nodorum blotch (also known as glume blotch), yellow or stripe rust, powdery mildew, Septoria tritici blotch (sometimes known as leaf blotch), brown or leaf rust, Fusarium head blight, tan spot and stem rust. In tropical areas, spot blotch (also known as a Helminthosporium leaf blight) is also important.

Wheat has also been the subject of mutation breeding, with the use of gamma, x-rays, ultraviolet light, and sometimes harsh chemicals. The varieties of wheat created through this method are in the hundreds (varieties being as far back as 1960), more of them being created in higher populated countries such as China.

2.4.1.6 Hulled versus free-threshing wheat

The four wild species of wheat, along with the domesticated varieties einkorn, emmer and spelt, have hulls. This more primitive morphology (in evolutionary terms) consists of toughened glumes that tightly enclose the grains, and (in domesticated wheats) a semi-brittle rachis that breaks easily on threshing. The result is that when threshed, the wheat ear breaks up into spikelets. To obtain the grain, further processing, such as milling or pounding, is needed to remove the hulls or husks. In contrast, in the free - threshing (or naked) forms such as durum wheat and common wheat, the flames are fragile and the rachis tough. On threshing, the chaff breaks up, releasing the grains. Hulled wheats are often stored as spikelets because the toughened glumes give good protection against pests of stored grain.

2.4.1.7 Naming

There are many botanical categorization systems used for wheat species, discussed in a separate article on Wheat taxonomy. The name of a wheat species from one information source may not be the name of a wheat species in another.

Within a species, wheat cultivars are further classified by wheat breeders and farmers in terms of:

- Growing season, such as winter wheat vs. Spring wheat.
- Protein content. Bread wheat protein content ranges from 10% in some soft wheats with high starch contents, to 15% in hard wheats.
- The quality of the wheat protein gluten. This protein can determine the suitability of a wheat to a particular dish. A strong and elastic gluten present in bread wheats enables the dough to trap carbon dioxide during leavening, but elastic gluten interferes with the rolling of pasta into thin sheets. The gluten protein in durum wheats used for pasta is strong but not elastic.
- Grain color (red, white or amber). Many wheat varieties are reddish-brown due to phenolic compounds present in the bran layer which are transformed to pigments by browning enzymes. White wheats have a lower content of phenolics and browning enzymes, and are generally less astringent in taste than red wheats. The yellowish color of durum wheat and semolina flour made from it is due to a carotenoid pigment called lutein, which can be oxidized to a colorless form by enzymes present in the grain.

2.4.1.8 As a food

Raw wheat can be ground into flour or, using hard durum wheat only, can be ground into semolina; germinated and dried creating malt; crushed or cut into cracked wheat; parboiled (or steamed), dried, crushed and de-branned into bulgur also known as groats. If the raw wheat is broken into parts at the mill, as is usually done, the outer husk or bran can be used several ways. Wheat is a major ingredient in such foods as bread, porridge, crackers, biscuits, Muesli, pancakes, pies, pastries, cakes, cookies, muffins, rolls, doughnuts, gravy, boza (a fermented beverage), and breakfast cereals (e.g., Wheatena, Cream of Wheat, Shredded Wheat, and Wheaties).

2.4.1.9 Nutrition

Much of the carbohydrate fraction of wheat is starch. Wheat starch is an important commercial product of wheat, but second in economic value to wheat gluten. The principal parts of wheat flour are gluten and starch. These can be separated in a kind of home experiments, by mixing flour and water to form a small ball of dough, and kneading it gently while rinsing it in a bowl of water. The starch falls out of the dough and sinks to the bottom of the bowl, leaving behind a ball of gluten.

In wheat, phenolic compounds are mainly found in the form of insoluble bound Ferulic acid and be relevant to resist to wheat fungal diseases. Alkylresorcinols are phenolic lipids present in high amounts in the bran layer (e.g. pericarp, testa and aleurone layers) of wheat and rye (0.1-0.3 % of dry weight).

2.4.1.10 Worldwide Consumption

Wheat is grown on more than 240,000,000 hectares (590,000,000 acres), larger than for any other crop. World trade in wheat is greater than for all other crops combined. With rice, wheat is the world's most favored staple food. Wheat provides more nourishment for humans than any other food source. It is a major diet component because of the wheat plant’s agronomic adaptability with the ability to grow from near arctic regions to the equator, from sea level to plains of Tibet, approximately 4,000 m (13,000 ft) above sea level. In addition to agronomic adaptability, wheat offers ease of grain storage and ease of converting grain into flour for making edible, palatable, interesting and satisfying foods. Wheat is the most important source of carbohydrate in a majority of countries.

Wheat protein is easily digested by nearly 99% of human population, as is its starch. Wheat also contains a diversity of minerals, vitamins and fats (lipids). With a small amount of animal or legume protein added, a wheat-based meal is highly nutritious.

The most common forms of wheat are white and red wheat. However, other natural forms of wheat exist. For example, in the highlands of Ethiopia grows purple wheat, a tetraploid species of wheat that is rich in anti-oxidants. Other commercially minor but nutritionally promising species of naturally evolved wheat species include black, yellow and blue wheat.

2.4.1.11 Production and consumption

In 2003, global per capita wheat consumption was 67 kg (148 lb), with the highest per capita consumption of 239 kg (527 lb) found in Kyrgyzstan. In 1997, global wheat consumption was 101 kg (223 lb) per capita, with the highest consumption 623 kg (1,373 lb) per capita in Denmark, but most of this (81%) was in animal feed. Wheat is the primary food staple in North Africa and the Middle East, and is growing in popularity in Asia. Unlike rice, wheat production is more widespread globally though China's share is almost one-sixth of the world.

"There is a little increase in yearly crop yield comparison to the year 1990. The reason for this is not in development of sowing area, but the slow and successive rising of the average yield. Average 2.5 tons wheat was produced on one hectare crop land in the world in the first half of 1990s, however this value was about 3 tons in 2009. In the world per capita wheat producing area continuously decreased between 1990 and 2009 considering the change of world population. There was no significant change in wheat producing area in this period. However due to the improvement of average yields there is some fluctuation in each year considering the per capita production, but there is no considerable decline. In 1990 per capita production was 111.98 kg/capita/year, while it was already 100.62 kg/capita/year in 2009. The decline is evident and the per capita production level of the year 1990 cannot be feasible simultaneously with the growth of world population in spite of the increased average yields. During the whole period the lowest per capita production was in 2006."

In the 20th century, global wheat output expanded by about 5-fold, but until about 1955 most of this reflected increases in wheat crop area, with lesser (about 20%) increases in crop yields per unit area. After 1955 however, there was a dramatic tenfold increase in the rate of wheat yield improvement per year, and this became the major factor allowing global wheat production to increase. Thus technological innovation and scientific crop management with synthetic nitrogen fertilizer, irrigation and wheat breeding were the main drivers of wheat output growth in the second half of the century. There were some significant decreases in the wheat crop area, for instance in North America.

Better seed storage and germination ability (and hence a smaller requirement to retain harvested crop for next year's seed) is another 20th century technological innovation. In Medieval England, farmers saved one-quarter of their wheat harvest as seed for the next crop, leaving only three-quarters for food and feed consumption. By 1999, the global average seed use of wheat was about 6% of output.

Several factors are currently slowing the rate of global expansion of wheat production: population growth rates are falling while wheat yields continue to rise, and the better the economic profitability of other crops such as soybeans and maize, linked with investment in modern genetic technologies, has promoted shifts to other crops.

However, the ever growing world population will certainly make it necessary to increase wheat production, especially if meat consumption grows in the developing countries, too. The reason for the latter is that to produce more meat more fodder is needed, and as a consequence wheat self-sufficiency level of the countries will go under the changes. If the human society once reaches such a high level of civilization that ensuring the well-being of few people does not endanger the life of others, then intensification of wheat production and hence establishing food security become an utmost important issue for everybody. And even if the current level of consumption is theoretically sustainable, there is another serious problem that we have to face: today people are dying of hunger in the world even apart from this problem. If we go beyond looking at the average consumption level on the global scale, we will face immense differences between the level of consumption in the different regions of the globe. There is a well known howling discrepancy between the developed and the developing world: namely, there is excess and at the same time wasting of food in the so-called modern societies, and on the other hand lack or undersupply of food in the poorer countries. People are suffering from overweight and its consequent illnesses in the developed world and on the other part of the world people are suffering from lack of food, from undernourishment and its consequent illnesses."

2.4.2 Rice

Rice is the seed of the monocot plants *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the grain with the second-highest worldwide production, after maize (corn), according to data for 2010.

Since a large portion of maize crops are grown for purposes other than human consumption, rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by humans.

Genetic evidence has shown that rice originates from a single domestication 8,200–13,500 years ago, in the Pearl River valley region of China. Previously, archaeological evidence had suggested that rice was domesticated in the Yangtze River valley region in China. From East Asia, rice spread to Southeast and South Asia. Rice was introduced to Europe through Western Asia, and to the Americas through European colonization.

There are many varieties of rice and culinary preferences tend to vary regionally. In some areas such as the Far East or Spain, there is a preference for softer and stickier varieties.

Rice is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce a Ratoon crop for up to 30 years. The rice plant can grow to 1–1.8 m (3.3–5.9 ft) tall, occasionally more depending on the variety and land fertility. It has long, slender leaves 50–100 cm (20–39 in) long and 2–2.5 cm (0.79–0.98 in) wide. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm (12–20 in) long. The edible seed is a grain (caryopsis) 5–12 mm (0.20–0.47 in) long and 2–3 mm (0.079–0.12 in) thick.

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

The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires sound planning and servicing of the water damming and channeling, but reduces the growth of less robust weed and pest plants that have no submerged growth state, and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the land.

The name **wild rice** is usually used for species of the grass genus *Zizania*, both wild and domesticated, although the term may also be used for primitive or uncultivated varieties of *Oryza*.

2.4.2.1 Preparation as food

The seeds of the rice plant are first milled using a rice huller to remove the chaff (the outer husks of the grain). At this point in the process, the product is called brown rice. The milling may be continued, removing the bran, *i.e.*, the rest of the husk and the germ, thereby creating white rice. White rice, which keeps longer, lacks some important nutrients; moreover, in a limited diet which does not supplement the rice, brown rice helps to prevent the disease beriberi.

Either by hand or in a rice polisher, white rice may be buffed with glucose or talc powder (often called polished rice, though this term may also refer to white rice in general), parboiled, or processed into flour. White rice may also be enriched by adding nutrients, especially those lost during the milling process. While the cheapest method of enriching involves adding a powdered blend of nutrients that will easily wash off (in the United States, rice which has been so treated requires a label warning against rinsing), more sophisticated methods apply nutrients directly to the grain, coating the grain with a water-insoluble substance which is resistant to washing.

In some countries, a popular form, parboiled rice, is subjected to a steaming or parboiling process while still a brown rice grain. This causes nutrients from the outer husk, especially thiamine, to move into the grain itself. The parboil process causes a gelatinisation of the starch in the grains. The grains become less brittle, and the color of the milled grain changes from white to yellow. The rice is then dried, and can then be milled as usual or used as brown rice. Milled parboiled rice is nutritionally superior to standard milled rice. Parboiled rice has an additional benefit in that it does not stick to the pan during cooking, as happens when cooking regular white rice. This type of rice is eaten in parts of India and countries of West Africa are also accustomed to consuming parboiled rice.

Despite the hypothetical health risks of talc (such as stomach cancer), talc-coated rice remains the norm in some countries due to its attractive shiny appearance, but it has been banned in some, and is no longer widely used in others (such as the United States). Even where talc is not used, glucose, starch, or other coatings may be used to improve the appearance of the grains.

Rice bran, called *nika* in Japan, is a valuable commodity in Asia and is used for many daily needs. It is a moist, oily inner layer which is heated to produce oil. It is also used as a pickling bed in making rice bran pickles and *Takuan*.

Raw rice may be ground into flour for many uses, including making many kinds of beverages, such as *amnesiac*, *horchata*, rice milk, and rice wine. Rice flour does not contain gluten, so is suitable for people on a gluten-free diet. Rice may also be made into various types of noodles. Raw, wild, or brown rice may also be consumed by raw-foodist or fruitarians if soaked and sprouted (usually a week to 30 days – gaba rice).

Processed rice seeds must be boiled or steamed before eating. Boiled rice may be further fried in cooking oil or butter (known as fried rice), or beaten in a tub to make *Mochi*.

Rice is a good source of protein and a staple food in many parts of the world, but it is not a complete protein: it does not contain all of the necessary amino acids in sufficient amounts for good health, and should be combined with other sources of protein, such as nuts, seeds, beans, fish, or meat.

Rice, like other cereal grains, can be puffed (or popped). This process takes advantage of the grains' water content and typically involves heating grains in a special chamber. Further puffing is sometimes accomplished by processing puffed pellets in a low-pressure chamber. The ideal gas law means either lowering the local pressure or raising the water temperature results in an increase in volume prior to water evaporation, resulting in a puffy texture. Bulk raw rice density is about 0.9 g/cm^3. It decreases to less than one-tenth that when puffed.

2.4.2.2 Cooking

The many varieties of rice, for many purposes, are distinguished as long-, medium-, and short-grain rices. The grains of fragrant long-grain rice (high amylose) tend to remain intact after cooking; medium-grain rice (high amylopectin) becomes more sticky. Medium-grain rice is used for sweet dishes, for *risotto* in Italy and many rice dishes, such as *arròs negre*, in Spain. Some varieties of long-grain rice are high in amylopectin, these are generally known as Thai Sticky rice, usually steamed. A stickier medium-grain rice is used for *sushi*; the stickiness lets the rice be moulded into a solid shape. Short-grain rice is often used for rice pudding.

Rice is cooked by boiling or steaming, and absorbs water during cooking. It can be cooked in just as much water as it absorbs (the absorption method), or in a large quantity of water which is drained before serving (the rapid-boil method). Electric rice cookers, popular in Asia and Latin America, simplify the process of cooking rice. Rice (or any other grain) is sometimes quickly fried in oil or fat before boiling (for example saffron rice or risotto); this makes the cooked rice less sticky, and is a cooking style commonly called pilaf by American chefs or Biryani (Dam-pukhtak) in India, Pakistan, and Iran.

In Arab cuisine, rice is an ingredient of many soups and dishes with fish, poultry, and other types of meat. It is also used to stuff vegetables or is wrapped in grape leaves (Dolma). When combined with milk, sugar, and honey, it is used to make desserts. In some regions, such as Tabaristan, bread is made using rice flour. Medieval Islamic texts spoke of medical uses for the plant.

Rice may also be made in Congee (also called rice porridge, fawrclaab, okayu, Xifan, jook, or rice gruel) by adding more water than usual, so that the cooked rice is saturated with water, usually to the point that it disintegrates. Rice porridge is commonly eaten as a breakfast food, and is also a traditional food for the sick.

Rice may be soaked prior to cooking, which saves fuel, decreases cooking time, minimizes exposure to high temperature and thus decreases the stickiness of the rice. For some varieties, soaking improves the texture of the cooked rice by rising expansion of the grains.

Instant rice differs from parboiled rice in that it is milled, fully cooked and then dried. There is a significant degradation in taste and texture.

A nutritionally superior method of preparing brown rice known as **GABA Rice** or GBR (germinated brown rice) may be used. This involves soaking washed brown rice for 20 hours in warm water (38 °C or 100 °F) prior to cooking it. This stimulates germination, which activates various enzymes in the rice. By this method, a result of research carried out for the United Nations International Year of Rice, it is possible to obtain a more complete amino acid profile, including GABA.

Rice flour and starch often are used in batters and breadings to increase crispiness.

2.4.2.3 Nutrients and the nutritional importance of rice

Rice is the staple food of over half the world's population. It is the predominant dietary energy source for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa. Rice provides 20% of the world’s dietary energy supply, while wheat supplies 19% and maize (corn) 5%.

A detailed study of nutrient content of rice suggests that the nutritional value of rice varies based on a number of factors. It depends on the strain of rice, that is between white, brown, black, red and purple varieties of rice – each prevalent in different parts of the world. It also depends on nutrient quality of the land rice is grown in, whether and how the rice is polished or processed, the manner it is enriched, and how it is prepared before consumption.

An illustrative comparison between white and brown rice of protein quality, mineral and vitamin quality, carbohydrate and fat quality suggests that neither is a complete nutritional source. Between the two, there is a significant difference in fiber content and minor differences in other nutrients.

Brilliantly colored rice strains, such as purple rice, derive their color from anthocyanins and tocols. Scientific studies suggest that these color pigments have antioxidant properties that may be useful to human health. In purple rice bran, hydrophilic antioxidants are in greater quantity and have higher free radical scavenging activity than lipophilic antioxidants. Anthocyanins and γ-tocols in purple rice are largely located in the inner portion of purple rice bran.

Comparative nutrition studies on red, black and white varieties of rice suggest that pigments in red and black rice varieties may offer nutritional benefits. Red or black rice consumption was found to reduce or retard the progression of atherosclerotic plaque development, induced by dietary cholesterol, in mammals. White rice consumption offered no similar benefits, and the study claims this to be due to absent antioxidants in red and black varieties of rice.

2.4.2.4 **Rice-growing environments**

Rice can be grown in different environments, depending upon water availability. Generally, rice does not thrive in a waterlogged area, yet it can survive and grow herein and it can also survive flooding.

1. **Lowland, rain-fed**, which is drought prone, favors medium depth; waterlogged, submergence, and flood prone
2. **Lowland, irrigated**, grown in both the wet season and the dry season
3. **Deep water** or floating rice
4. **Coastal Wetland**
5. **Upland rice** is also known as **Ghaiya rice**, well known for its drought tolerance

2.4.2.5 History of domestication and cultivation

2.4.2.5.1 Asia

There have been plenty of debates on the origins of the domesticated rice. Genetic evidence published in the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) shows that all forms of Asian rice, both *indica* and *japonica*, spring from a single domestication that occurred 8,200–13,500 years ago in China of the wild rice *Oryza rufipogon*. A 2012 study published in *Nature*, through a map of rice genome variation, indicated that the domestication of rice occurred in the Pearl River valley region of China. From East Asia, rice was spread to South and Southeast Asia. Before this research, the commonly accepted view, based on archaeological evidence, is that rice was first domesticated in the region of the Yangtze River valley in China.

Morphological studies of rice phytoliths from the Diaotonghuan archaeological site clearly show the transition from the collection of wild rice to the cultivation of domesticated rice. The large number of wild rice phytoliths at the Diaotonghuan level dating from 12,000–11,000 BP indicates that the wild rice collection was part of the local means of subsistence. Changes in the morphology of Diaotonghuan phytoliths dating from 10,000–8,000 BP show that rice had by this time been domesticated. Soon afterwards the two major varieties of indica and japonica rice were being grown in Central China. In the late 3rd millennium BC, there was a rapid expansion of rice cultivation in mainland Southeast Asia and westwards across India and Nepal.

In 2003, Korean archaeologists claimed to have discovered the world's oldest domesticated rice. Their 15,000-year old age challenges the accepted view that rice cultivation originated in China about 12,000 years ago. These findings were received by academia with strong skepticism, and the results and their publicizing have been cited as being driven by a combination of nationalist and regional interests. In 2011, a combined effort by the Stanford University, New York University, Washington University in St. Louis, and Purdue University have provided the strongest evidence yet that there is only one single origin of domesticated rice, in the Yangtze Valley of China.

The earliest remains of the grain in the Indian subcontinent have been found in the Indo-Gangetic Plain and date from 7000–6000 BC though the earliest widely accepted date for cultivated rice is placed at around 3000–2500 BC with findings in regions belonging to the Indus Valley Civilization. Perennial wild rices still grow in Assam and Nepal. It seems to have appeared around 1400 BC in southern India after its domestication in the northern plains. It then spread all the fertile alluvial plains watered by rivers. Cultivation and cooking methods are thought to have spread to the west rapidly and by medieval times, southern Europe saw the introduction of rice as a hearty grain.

According to Zohary and Hopf (2000, p. 91), *O. sativa* was recovered from a grave at Susa in Iran (dated to the 1st century AD) at one end of the ancient world, another domestication of rice in South Asia.

Today, the majority of all rice produced comes from China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Pakistan, Philippines, and Japan. Asian farmers still account for 92% of the world's total rice production.

2.4.2.5.2 ***Sri Lanka***

Rice is the staple food amongst all the ethnic groups in Sri Lanka. Agriculture in Sri Lanka mainly depends on the rice cultivation. Rice production is acutely dependent on rainfall and the government supply necessity of water through irrigation channels throughout the cultivation seasons. The principal cultivation season, known as "Maha", is from October to March and the subsidiary cultivation season, known as "Yala", is from April to September. During Maha season, there is usually enough water to sustain the cultivation of all rice fields, nevertheless in Yala season there is only enough water for cultivation of half of the land extent.

Traditional rice varieties are now making a comeback with the recent interest in green foods.

2.4.2.5.3 ***Companion plant***

One of the earliest known examples of companion planting is the growing of rice with Azolla, the mosquito fern, which covers the top of a fresh rice paddy's water, blocking out any competing plants, as well as fixing nitrogen from the atmosphere for the rice to use. The rice is planted when it is tall enough to poke out above the azolla. This method has been used for at least a thousand years.

2.4.2.5.4 **Africa**

African rice has been cultivated for 3500 years. Between 1500 and 800 BC, *Oryza glaberrima* propagated from its original center, the Niger River delta, and extended to Senegal. However, it never developed far from its original region. Its cultivation even declined in favor of the Asian species, which was introduced to East Africa early in the common area and spread westward. African rice helped Africa conquer its famine of 1203.

2.4.2.5.5 **Middle East**

Rice was grown in some areas of southern Iraq. With the rise of Islam it moved north to Nisibin, the southern shores of the Caspian Sea (Iran) and then beyond the Muslim world into the valley of the Volga. In Egypt, rice is mainly grown in the Nile Delta. In Israel, rice came to be grown in the Jordan Valley. Rice is also grown in Saudi Arabia at Al-hasa Oasis and in Yemen.

2.4.2.5.6 **Europe**

Rice was known to the Classical world, being imported from Egypt, and perhaps west Asia. It was known to Greece by returning soldiers from Alexander the Great's military expedition to Asia. Large deposits of rice from the first century A.D. have been found in Roman camps in Germany.

The Moors brought Asiatic rice to the Iberian Peninsula in the 10th century. Records indicate it was grown in Valencia and Majorca. In Majorca, rice cultivation seems to have stopped after the Christian conquest, although historians are not certain.

Muslims also brought rice to Sicily, where it was an important crop long before it is noted in the plain of Pisa (1468) or in the Lombard plain (1475), where its cultivation was promoted by Ludovico Sforza, Duke of Milan, and demonstrated in his model farms.

After the 15th century, rice spread throughout Italy and then France, later propagating to all the continents during the age of European exploration.

In European Russia, rice has been grown in the Krasnodar Krai, and known in Russia as "rice from Kuban".

2.4.2.5.7 **Caribbean and Latin America**

Rice is not native to the Americas but was introduced to Latin America and the Caribbean by European colonizers at an early date with the Spanish colonizers introducing Asian rice to Mexico in the 1520s at Veracruz and the Portuguese and their African slaves introducing it at about the same time to Colonial Brazil. Recent scholarship suggests that enslaved Africans played an active role in the establishment of rice in the New World and that African rice was an important crop from an early period. Varieties of rice and bean dishes that were a staple dish along the peoples of West Africa remained a staple among their descendants subjected to slavery in the Spanish New World colonies, Brazil and elsewhere in the Americas.

The Native Americans of what is now the Eastern United States may have practiced extensive agriculture with forms of wild rice.

2.4.2.5.8 **United States**

In 1694, rice arrived in South Carolina, probably originating from Madagascar.

In the United States, colonial South Carolina and Georgia grew and amassed great wealth from the slave labor obtained from the Senegambia area of West Africa and from coastal Sierra Leone. At the port of Charleston, through which 40% of all American slave imports passed, slaves from this region of Africa brought higher prices due to their prior knowledge of rice culture, which was put to use on the many rice plantations around Georgetown, Charleston, and Savannah.

From the enslaved Africans, plantation owners learned how to dyke the marshes and periodically flood the fields. At first the rice was laboriously milled by hand using large mortars and pestles made of wood, then winnowed in Sweetgrass baskets (the making of which was another skill brought by slaves from Africa). The invention of the rice mill increased profitability of the crop, and the addition of water power for the mills in 1787 by millwright Jonathan Lucas was another step forward.

Rice culture in the southeastern U.S. became less profitable with the loss of slave labor after the American Civil War, and it finally died out just after the turn of the 20th century. Today, people can visit the only remaining rice plantation in South Carolina that still has the original winnowing barn and a rice mill from the mid-19th century at the historic Mansfield Plantation in Georgetown, South Carolina. The predominant strain of rice in the Carolinas was from Africa and was known as "Carolina Gold." The cultivar has been preserved and there are current attempts to reintroduce it as a commercially grown crop.

In the southern United States, rice has been grown in southern Arkansas, Louisiana, and East Texas since the mid-19th century. Many Cajun farmers grew rice in wet marshes and low lying prairies where they could also farm crayfish when the fields were flooded. In recent years rice production has risen in North America, especially in the Mississippi River Delta areas in the states of Arkansas and Mississippi.

Rice cultivation began in California during the California Gold Rush, when an estimated 40,000 Chinese laborers immigrated to the state and grew small amounts of the grain for their own consumption. However, commercial production began only in 1912 in the town of Richvale in Butte County. By 2006, California produced the second largest rice crop in the United States, after Arkansas, with production concentrated in six counties north of Sacramento. Unlike the Mississippi Delta region, California's production is dominated by short- and medium-grain *japonica* varieties, including cultivars developed for the local climate such as Calrose, which makes up as much as 85% of the state's crop.

More than 100 varieties of rice are commercially produced primarily in six states (Arkansas, Texas, Louisiana, Mississippi, Missouri, and California) in the U.S. According to estimates for the 2006 crop year, rice production in the U.S. is valued at $1.88 billion, approximately half of which is expected to be exported. The U.S. provides about 12% of world rice trade. The majority of domestic utilization of U.S. rice is direct food use (58%), while 16% is used in each of processed foods and beer. 10% is found in pet food.

2.4.2.5.9 **Australia**

Rice was one of the earliest crops planted in Australia by British settlers, who had experience with rice plantations in the Americas and India.

Although attempts to grow rice in the well-watered north of Australia have been made for many years, they have consistently failed because of inherent iron and manganese toxicities in the lands and destruction by pests.

In the 1920s it was seen as a possible irrigation crop on lands within the Murray-Darling Basin that were too heavy for the cultivation of fruit and too infertile for wheat.

Because irrigation water, despite the extremely low runoff of temperate Australia, was (and remains) very cheap, the growing of rice was taken up by agricultural groups over the following decades. Californian varieties of rice were found suitable for the climate in the Riverina, and the first mill opened at Leeton in 1951.

Even before this Australia's rice production greatly exceeded local needs, and rice exports to Japan have become a major source of foreign currency. Above-average rainfall from the 1950s to the middle 1990s encouraged the expansion of the Riverina rice industry, but its prodigious water use in a practically waterless region began to attract the attention of environmental scientists. These became severely concerned with the declining flow in the Snowy River and the lower Murray River.

Although rice growing in Australia is highly profitable due to the cheapness of land, several recent years of severe drought have led many to call for its elimination because of its effects on extremely fragile aquatic ecosystems. The Australian rice industry is somewhat opportunistic, with the area planted varying significantly from season to season depending on water in the Murray and Murrumbidgee irrigation regions.

2.4.2.6 Production and commerce

Top 20 Rice Producers by Country—2011
(million metric ton)

People's Republic of China	202.6
India	155.7
Indonesia	65.7
Bangladesh	50.6
Vietnam	42.3
Thailand	34.5
Burma	32.8
Philippines	16.6
Brazil	13.5
Pakistan	9.2
Cambodia	8.8
Japan	8.4
United States	8.3
South Korea	6.3
Egypt	5.6
Nigeria	4.5
Nepal	4.4
Madagascar	4.3

Sri Lanka	3.9
Iran	3.2

Source: Food and Agriculture Organization

2.4.2.7 **Production**

Rice is a major food staple and a mainstay for the rural population and their food security. It is mainly cultivated by small farmers in holdings of less than 1 hectare. Rice is also a wage commodity for workers in the cash crop or non-agricultural sectors. Rice is vital for the nutrition of much of the population in Asia, as well as in Latin America and the Caribbean and in Africa; it is central to the food security of over half the world population. Developing countries account for 95% of the total production, with China and India alone responsible for nearly half of the world output.

World production of rice has risen steadily from about 200 million tonnes of paddy rice in 1960 to over 678 million tonnes in 2009. The three largest producers of rice in 2009 were China (197 million tonnes), India (131 Mt), and Indonesia (64 Mt). Among the six largest rice producers, the most productive farms for rice, in 2009, were in China producing 6.59 tonnes per hectare. At 44 million hectares, India had the largest farm area under rice production in 2009. The rice farm productivity in India was about 45% of the rice farm productivity in China, and about 60% of the rice farm productivity in Indonesia.

If India could adopt the farming knowledge and technology in use in China and Indonesia, India could produce an additional 100 million tonnes of rice, enough staple food for about 400 million people every year, and US$50 billion in additional annual income to its rice farmers (adjusted to 2010 dollars and global rice prices per tonne). In the 1990s, genetic studies took place in many European laboratories to increase rice production per hectare. Most of them were Dutch agricultural organizations united by HNGAC. These studies were later stopped due to lack of funding.

In addition to the gap in farming system technology and knowledge, many rice grains producing countries have significant losses post-harvest at the farm and because of poor roads, inadequate storage technologies, inefficient supply chains and farmer's inability to bring the produce into retail markets dominated by small shopkeepers. A World Bank – FAO study claims 8% to 26% of rice is lost in developing nations, on average, every year, because of post-harvest problems and poor infrastructure. Some sources claim the post-harvest losses to exceed 40%.,

Not only do these losses reduce food security in the world, the study claims that farmers in developing countries such as China, India and others lose approximately US$89 billion of income in preventable post-harvest farm losses, poor transport, the lack of proper storage and retail. One study claims that if these post-harvest grain losses could be eliminated with better infrastructure and retail network, in India alone enough food would be saved every year to feed 70 to 100 million people over a year.

2.4.2.8 **Harvesting, drying and milling**

Unmilled rice, known as paddy (Indonesia and Malaysia: paid; Philippines, Palay), is usually harvested when the grains have a moisture content of around 25%. In most Asian countries, where rice is almost entirely the product of smallholder agriculture, harvesting is carried out manually, although there is a growing interest in mechanical harvesting. Harvesting can be carried out by the farmers themselves, but is also frequently done by seasonal Labor groups. Harvesting is followed by threshing, either immediately or within a day or two. Again, much threshing is still carried out by hand but there is a rising use of mechanical threshers. Subsequently, paddy needs to be dried to bring down the moisture content to no more than 20% for milling.

A familiar sight in several Asian countries is paddy laid out to dry along roads. However, in most countries the bulk of drying of marketing paddy takes place in mills, with village-level drying is used for paddy to be consumed by farm families. Mills either sun dry or use mechanical driers or both. Drying has to be carried out quickly to avoid the formation of moulds. Mills range from simple hullers, with a throughput of a couple of tonnes a day, that's simply remove the outer husk, to enormous operations that can process 4,000 tonnes a day and produce highly polished rice. A good mill can achieve a paddy-to-rice conversion rate of up to 72% but smaller, inefficient mills often struggles to achieve 60%. These smaller mills often do not buy paddy and sell rice but only service farmers who want to mill their paddy for their own consumption.

2.4.2.9 **Distribution**

Because of the importance of rice to human nutrition and food security in Asia, the domestic rice markets tend to be subject to considerable state involvement. While the private sector plays a leading role in most countries, agencies such as BULOG in Indonesia, the NFA in the Philippines, VINAFOOD in Vietnam and the Food Corporation of India are all heavily involved in the purchasing of paddy from farmers or rice from mills and in distributing rice to poorer people. BULOG and NFA monopolize rice imports into their countries while VINAFOOD controls all exports from Vietnam.

2.4.2.10 **Trade**

World trade figures are very different to those for production, as less than 8% of rice produced is traded internationally. In economic terms, the global rice trade was a small fraction of 1% of world mercantile trade. Many countries consider rice as a strategic food staple, and various governments subject its trade to a wide range of controls and interventions.

Developing countries are the main players in the world rice trade, accounting for 83% of exports and 85% of imports. While there are numerous importers of rice, the exporters of rice are limited. Just five countries – Thailand, Vietnam, China, the United States and India – in decreasing order of exported quantities, accounted for about three-quarters of world rice exports in 2002. However, this ranking has been rapidly changing in recent years. In 2010, the three largest exporters of rice, in decreasing order of quantity exported were Thailand, Vietnam and India. By 2012, India became the largest exporter of rice with a 100% increase in its exports on a year to year basis, and Thailand slipped to third position. Together, Thailand, Vietnam and India accounted for nearly 70% of the world rice exports.

The primary variety exported from Thailand and Vietnam were Jasmine rice, while exports from India included an aromatic Basmati variety. China, an exporter of rice in early 2000s, was a net importer of rice in 2010 and will become the largest net importer, surpassing Nigeria, in 2013. According to a USDA report, the world's largest exporters of rice in 2012 were India (9.75 million tonnes), Vietnam (7 million tonnes), Thailand (6.5 million tonnes), Pakistan (3.75 million tonnes) and the United States (3.5 million tonnes).

Major importers usually include Nigeria, Indonesia, Bangladesh, Saudi Arabia, Iran, Iraq, Malaysia, the Philippines, Brazil and some African and Persian Gulf countries. Although China and India are the two largest producers of rice in the world, both countries consume the majority of the rice produced domestically, leaving little to be traded internationally.

2.4.2.11 The world's most productive rice farms and farmers

The average would yield of rice was 4.3 tonnes per hectare, in 2010.

Australian rice farms were the most productive in 2010, with a nationwide average of 10.8 tonnes per hectare.

Yuan Longping of China National Hybrid Rice Research and Development Center, China, set a world record for rice yield in 2010 at 19 tonnes per hectare on a demonstration plot. In 2011, this record was surpassed by an Indian farmer, Sumant Kumar, with 22.4 tonnes per hectare in Bihar. Both these farmers claim to have employed newly developed rice breeds and the System of Rice Intensification (SRI), a recent innovation in rice farming. SRI is claimed to have set new national records in rice yields, within the last 10 years, in many countries. The claimed Chinese and Indian yields have yet to be demonstrated on seven-hectare lots and to be reproducible over two consecutive years on the same farm.

2.4.2.12 Price

In late 2007 to May 2008, the price of grains rose greatly due to droughts in major producing countries (particularly Australia), increased use of grains for animal feed and US subsidies for bio-fuel production. Although there was no shortage of rice on world markets this general upward trend in grain prices led to panic buying by consumers, government rice export bans (in particular, by Vietnam and India) and inflated import orders by the Philippines marketing board, the National Food Authority. This caused significant rises in rice prices. In late April 2008, prices hit 24 US cents a pound, twice the price of seven months earlier. Over the period of 2007 to 2013, the Chinese government has substantially increased the price it pays domestic farmers for their rice, rising to US$500 per metric ton by 2013. The 2013 price of rice originating from other Southeast Asian countries was a comparably low US$350 per metric ton.

On April 30, 2008, Thailand announced plans for the creation of the Organization of Rice Exporting Countries (OREC) with the intention that this should develop into a price-fixing cartel for rice. However, little progress had been made by mid-2011 to achieve this.

2.4.2.13 Worldwide consumption

Food consumption of rice by country – 2009
(million metric ton of paddy equivalent)

World Total	531.6
People's Republic of China	156.3
India	123.5
Indonesia	45.3

Bangladesh	38.2
Vietnam	18.4
Philippines	17.0
Thailand	13.7
Japan	10.2
Burma	10.0
Brazil	10.0
South Korea	5.8
Nigeria	4.8
Egypt	4.6
Pakistan	4.3
USA	3.8
Nepal	3.5
Cambodia	3.4
Sri Lanka	3.2
Madagascar	3.2
Malaysia	3.1
North Korea	2.8

As of 2009 world food consumption of rice was 531.6 million metric tons of paddy equivalent (354,603 of milled equivalent), while the far largest consumers were China consumes 156.3 million metric tons of paddy equivalent (29.4% of the world consumption) and India consumes 123.5 million metric tons of paddy equivalent (23.3% of the world consumption). Between 1961 and 2002, per capita consumption of rice increased by 40%.

Rice is the most important crop in Asia. In Cambodia, for example, 90% of the total agricultural area is used for rice production.

U.S. rice consumption has risen sharply over the past 25 years, fueled in part by commercial applications such as beer production. Almost one in five adult Americans now report eating at least half a serving of white or brown rice per day.

2.4.2.14 Environmental impacts

Rice cultivation on wetland rice fields is thought to be responsible for 1.5% of the anthropogenic methane emissions. Rice requires slightly more water to produce than other grains.

Long-term flooding of rice fields cuts the land off from atmospheric oxygen and causes anaerobic fermentation of organic matter in the land. Methane production from rice cultivation contributes ~1.5% of anthropogenic greenhouse gases. Methane is twenty times more potent a greenhouse gas than carbon dioxide.

A 2010 study found that, as a result of rising temperatures and decreasing solar radiation during the later years of the 20th century, the rice yield growth rate has decreased in many parts of Asia, compared to what would have been observed had the temperature and solar radiation trends not occurred. The yield growth rate had fallen 10–20% at some places. The study was based on records from 227 farms in Thailand, Vietnam, Nepal, India, China, Bangladesh, and Pakistan. The mechanism of this falling yield was not clear, but might involve increased respiration during warm nights, which expends energy without being able to photosynthesize.

2.4.3 Sugar cane

Sugarcane, or **Sugar cane**, is any of six to 37 species (depending on which taxonomic system is used) of tall perennial true grasses of the genus *Saccharum*, tribe Andropogoneae, native to the warm temperate to tropical regions of South Asia.

They have stout jointed fibrous stalks that are rich in sugar, and measure two to six meters (6 to 19 feet) tall. All sugar cane species interbreed and the major commercial cultivars are complex hybrids.

Sugarcane belongs to the grass family (Poaceae), an economically important seed plant family that includes maize, wheat, rice, and sorghum and many forage crops. The main product of sugarcane is sucrose, which accumulates in the stalk internodes. Sucrose, extracted and purified in specialized mill factories, is used as raw material in human food industries or is fermented to produce ethanol. Ethanol is produced on a large scale by the Brazilian sugarcane industry.

Sugar cane is the world's largest crop. In 2010, FAO estimates it was cultivated on about 23.8 million hectares, in more than 90 countries, with a worldwide harvest of 1.69 billion tons. Brazil was the largest producer of sugar cane in the world. The next five major producers, in decreasing amounts of production, were India, China, Thailand, Pakistan and Mexico.

The world demand for sugar is the primary driver of sugarcane agriculture. Cane accounts for 80% of sugar produced; most of the rest is made from sugar beets. Sugarcane predominantly grows in the tropical and subtropical regions, and sugar beet predominantly grows in colder temperate regions of the world. Other than sugar, products derived from sugarcane include Falernum, molasses, rum, *cachaça* (a traditional spirit from Brazil), bagasse and ethanol. In some regions, people use sugar cane reeds to make pens, mats, screens, and thatch. The young unexpanded inflorescence of *tebu telor* is eaten raw, steamed or toasted, and prepared in various ways in certain island communities of Indonesia.

In India, between the sixth and fourth centuries BC, the Persians, followed by the Greeks, discovered the famous "reeds that produce honey without bees". They adopted and then spread sugar and sugarcane agriculture. A few merchants began to trade in sugar—a luxury and an expensive spice until the 18th century. Before the 18th century, the cultivation of sugar cane was largely confined to India. Sugar cane plantations, like cotton farms, were a major driver of large human migrations in the 19th and early 20th century, influencing the ethnic mix, political conflicts and cultural evolution of various Caribbean, South American, Indian Ocean and Pacific island nations.

2.4.3.1 Cultivation

Sugarcane cultivation requires a tropical or temperate climate, with a minimum of 60 centimeters (24 in) of annual moisture. It is one of the most efficient photosynthesizers in the plant kingdom. It is a C_4 plant, able to convert up to one percent of incident solar energy into biomass. In prime growing regions, such as Mauritius, Dominican Republic, Puerto Rico, India, Indonesia, Pakistan, Peru, Brazil, Bolivia, Colombia, Australia, Ecuador, Cuba, the Philippines, El Salvador and Hawaii, sugarcane crop can produce over 15 kilograms of cane per square meter of sunshine.

Sugar cane is cultivated in the tropics and subtropics in areas with plentiful supply of water, for a continuous period of more than six to seven months each year, either from natural rainfall or through irrigation. The crop does not tolerate severe frosts. Therefore, most of the world's sugarcane is grown between 22°N and 22°S, and some up to 33°N and 33°S. When sugarcane crop is found outside this range, such as the Natal region of South Africa, it is normally due to anomalous climatic conditions in the region such as warm ocean currents that sweep down the coast. In terms of altitude, sugarcane crop is found up to 1,600 m close to the equator in countries such as Colombia, Ecuador and Peru.

Sugar cane can be grown on many lands ranging from highly fertile well drained mollisols, through heavy cracking vertisols, infertile acid oxisols, peaty histosols to rocky andisols. Both plentiful sunshine and water supplies increase cane production. This has made desert countries with better irrigation facilities such as Egypt as some of the highest yielding sugarcane cultivating regions.

Although sugarcanes produce seeds, modern stem cutting has become the most common reproductive method. Each cutting must contain at least one bud, and the cuttings are sometimes hand-planted. In more technologically advanced countries like the United States and Australia, billet planting is common. Billets harvested from a mechanical harvester are planted by a machine that opens and recloses the ground. Once planted, a stand can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons. Successive harvests give decreasing yields, eventually justifying replanting. Two to 10 harvests are usually made depending on the type of culture. In a country with a mechanical agriculture looking for a high production of large fields like in North America, sugar canes are replanted after two or three harvests to avoid a lowering in yields. In countries with a more traditional type of agriculture with smaller fields and hand harvesting, like in the French island la Réunion, sugar canes are often harvested up to 10 years before replanting.

Sugarcane is harvested by hand and mechanically. Hand harvesting accounts for more than half of production, and is dominant in the developing world. In hand harvesting, the field is first set on fire. The fire burns dry leaves, and chases or kills any lurking venomous snakes, without harming the stalks and roots. Harvesters then cut the cane just above ground-level using cane knives or machetes. A skilled harvester can cut 500 kilograms (1,100 lb) of sugarcane per hour.

Mechanical harvesting uses a combine, or sugar cane harvester. The Austoft 7000 series, the original modern harvester design, has now been copied by other companies, including Cameco / John Deere. The machine cuts the cane at the base of the stalk, strips the leaves, chops the cane into consistent lengths and deposits it into a transporter following alongside. The harvester then blows the trash back onto the field. Such machines can harvest 100 long tons (100 t) each hour; however, harvested cane must be rapidly processed. Once cut, sugarcane begins to lose its sugar content, and damage to the cane during mechanical harvesting accelerates this decline. This decline is offset because a modern chopper harvester can complete the harvest faster and more efficiently than hand cutting and loading. Austoft also developed a series of hydraulic high-lift infield transporters to work alongside their harvesters to allow even more rapid transfer of cane to, for example, the nearest railway siding. This mechanical harvesting doesn't require the field to be set on fire; the remains left in the field of the machine consist of the top of the sugar cane and the dead leaves, which act as mulch for the next round of planting.

2.4.3.2 Pests

The cane beetle (also known as cane grub) can substantially reduce crop yield by eating roots; it can be controlled with imidacloprid (Confidor) or chlorpyrifos (Lorsban). Other important pests are the larvae of some butterfly/moth species, including the turnip moth, the sugarcane borer (*Diatraea saccharalis*), the Mexican rice borer (*Eoreuma loftini*); leaf-cutting ants, termites, spittlebugs (especially *Mahanarva fimbriolata* and *Deois flavopicta*), and the beetle *Migdolus fryanus*. The planthopper insect *Eumetopina flavipes* acts as a virus vector, which causes the sugarcane disease ramu stunt.

2.4.3.2 Pathogens

Numerous pathogens infect sugar cane, such as sugarcane grassy shoot disease caused by *Phytoplasma*, whiptail disease or sugarcane smut, *pokkah boeng* caused by *Fusarium moniliforme*, Xanthomonas Axonopodis bacteria causes Gumming Disease, and red rot disease caused by *Colletotrichum falcatum*. Viral diseases affecting sugarcane include sugarcane mosaic virus, maize streak virus, and sugarcane yellow leaf virus.

2.4.3.3 Nitrogen fixation

Some sugarcane varieties are capable of fixing atmospheric nitrogen in association with the bacterium *Glucoacetobacter diazotrophicus*. Unlike legumes and other nitrogen-fixing plants that form root nodules in the land in association with bacteria, *G. diazotrophicus* lives within the intercellular spaces of the sugarcane's stem. Coating seeds with the bacteria is a newly-developed technology that can enable every crop species to fix nitrogen for its own use.

2.4.3.4 Processing

Traditionally, sugarcane processing requires two stages. Mills extract raw sugar from freshly harvested cane, and sometimes bleach it to make "mill white" sugar for local consumption. Refineries, often located nearer to consumers in North America, Europe, and Japan, then produce refined white sugar, which is 99 percent sucrose. These two stages are slowly merging. Rising affluence in the sugar-producing tropics increased demand for refined sugar products, driving a trend toward combined milling and refining.

2.4.3.5 Milling

Sugarcane processing produces **cane sugar** (sucrose) from sugar cane. Other products of the processing include bagasse, molasses, and filter cake.

Bagasse, the residual dry fiber of the cane after cane juice has been extracted, is used for several purposes:

- Fuel for the boilers and kilns,
- Producing of paper, paperboard products and reconstituted Panelboard,
- Agricultural mulch, and
- As a raw material for production of chemicals.

The primary use of bagasse and bagasse residue is as a fuel source for the boilers in the generation of process steam in sugar plants. Dried filtercake is used as an animal feed supplement, fertilizer, and source of sugar cane wax. Molasses is produced in two forms: blackstrap that is not edible, and a syrup that is edible. Blackstrap molasses is used primarily as an animal feed additive but also is used to produce ethanol, compressed yeast, citric acid, and rum. Edible molasses syrups are often blended with maple syrup, invert sugars, or corn syrup.

2.4.3.6 Refining

Sugar refining further purifies the raw sugar. It is first mixed with heavy syrup and then centrifuged in a process called "affination". Its purpose is to wash away the sugar crystals' outer coating, which is less pure than the crystal interior. The remaining sugar is then dissolved to make a syrup, about 60 percent solids by weight.

The sugar solution is clarified by the addition of phosphoric acid and calcium hydroxide, which combine to precipitate calcium phosphate. The calcium phosphate particles entrap some impurities and absorb others, and then float to the top of the tank, where they can be skimmed off. An alternative to this "phosphatation" technique is "carbonatation", which is similar, but uses carbon dioxide and calcium hydroxide to produce a calcium carbonate precipitate.

After filtering any remaining solids, the clarified syrup is decolorized by filtration through activated carbon. Bone char or coal-based activated carbon is traditionally used in this role. Some remaining color-forming impurities adsorb to the carbon. The purified syrup is then concentrated to supersaturation and repeatedly crystallized in a vacuum, to produce white refined sugar. As in a sugar mill, the sugar crystals are separated from the molasses by centrifuging. Additional sugar is recovered by blending the remaining syrup with the washings from affination and again crystallizing to produce brown sugar. When no more sugar can be economically recovered, the final molasses still contains 20–30 percent sucrose and 15–25 percent glucose and fructose.

To produce granulated sugar, in which individual grains do not clump, sugar must be dried, first by heating in a rotary dryer, and then by blowing cool air through it for several days.

2.4.3.7 Ribbon cane syrup

Ribbon cane is a subtropical type that was once widely grown in the southern United States, as far north as coastal North Carolina. The juice was extracted with horse or mule-powered crushers; the juice was boiled, like maple syrup, in a flat pan, and then used in the syrup form as a food sweetener. It is not currently a commercial crop, but a few growers find ready sales for their product.

2.4.3.8 Pollution from sugar cane processing

Particulate matter, combustion products, and volatile organic compounds are the primary pollutants emitted during the sugarcane processing. Combustion products include nitrogen oxides (NO_X), carbon monoxide (CO), CO_2, and sulfur oxides (SO_X). Potential emission sources include the sugar granulators, sugar conveying and packaging equipment, bulk loadout operations, boilers, granular carbon and char regeneration kilns, regenerated adsorbent transport systems, kilns and handling equipment (at some facilities), carbonation tanks, multi-effect evaporator stations, and vacuum boiling pans. Modern pollution prevention technologies are capable of addressing all of these potential pollutants.

2.4.3.9 Bagasse applications

Sugar cane is a major crop in many countries. It is one of the plants with the highest bioconversion efficiency. Sugarcane crop is able to efficiently fix solar energy, yielding some 55 tonnes of dry matter per hectare of land annually. After harvest, the crop produces sugar juice and bagasse, the fibrous dry matter. This dry matter is biomass with potential as fuel for energy production.

Sugar cane bagasse is a potentially abundant source of energy for large producers of sugar cane, such as Brazil, India and China. According to one report, with use of latest technologies, bagasse produced annually in Brazil has the potential of meeting 20 percent of Brazil's energy consumption by 2020.

2.4.3.10 Electricity production

A number of countries, in particular those devoid of any fossil fuel, have implemented energy Protection and efficiency measures to minimize energy utilized in cane processing and furthermore export any excess electricity to the grid. Bagasse is usually burned to produce steam, which in turn creates electricity. Current technologies, such as those in use in Mauritius, produces over 100 kWh of electricity per tonne of bagasse. With a total world harvest of over 1 billion tonnes of sugar cane per year, the global energy potential from bagasse is over 100,000 GWh. Using Mauritius as a reference, an annual potential of 10,000 GWh of additional electricity could be produced throughout Africa. Electrical generation from bagasse could become quite important, particularly to the rural populations of sugarcane producing nations.

Recent cogeneration technology plants are being designed to produce from 200 to over 300 kWh of electricity per tonne of bagasse. As sugarcane is a seasonal crop, shortly after harvest the supply of bagasse would peak, requiring power generation plants to strategically manage the storage of bagasse.

2.4.3.11 Biogas production

A greener alternative to burning bagasse for the production of electricity is to convert bagasse into biogas. Technologies are being developed to use enzymes to transform bagasse into advanced biofuel and biogas. Not only could this process realize a greater energy potential, the release of greenhouse gasses would be drastically less than simply burning bagas.

2.4.4 Tea

Tea is an aromatic beverage commonly prepared by pouring hot or boiling water over cured leaves of the tea plant, *Camellia sinensis*. After water, tea is the most widely consumed beverage in the world. It has a cooling, slightly bitter, and astringent flavor that many people enjoy.

Tea likely originated in China as a medicinal drink. It was first introduced to Portuguese priests and merchants in China during the 16th century. Drinking tea became popular in Britain during the 17th century. The British introduced it to India, in order to compete with the Chinese monopoly on the product.

Tea has long been promoted for having a variety of positive health benefits. Recent studies suggest that green tea may help reduce the risk of cardiovascular disease and some forms of cancer, promote oral health, reduce blood pressure, help with weight control, improve antibacterial and antivirasic activity, provide protection from solar ultraviolet light, and increase bone mineral density. Green tea is also said to have "anti-fibrotic properties, and neuroprotective power." Additional research is needed to "fully understand its contributions to human health, and advise its regular consumption in Western diets."

Tea catechins have known anti-inflammatory and neuroprotective properties, help regulate food intake, and have an affinity for cannabinoid receptors, which may suppress pain and nausea and provide calming effects.

Consumption of green tea is associated with a lower risk of diseases that cause functional disability, such as “stroke, cognitive impairment, and osteoporosis” in the elderly.

Tea contains L-theanine, an amino acid whose consumption is strongly associated with a calm but alert and focused, relatively productive (alpha wave-dominant) mental state in humans. This mental state is also common to meditative practice.

The phrase "herbal tea" usually refers to infusions of fruit or herbs made without the tea plant, such as rosehip tea, chamomile tea, or rooibos tea. Alternative phrases for this are tisane or herbal infusion, both bearing an implied contrast with "tea" as it is construed here.

2.4.4.1 **Cultivation and harvesting**

Camellia sinensis is an evergreen plant that grows mainly in tropical and subtropical climates. Some varieties can also tolerate marine climates and are cultivated as far north as Pembrokeshire in the British mainland and Washington in the United States.

Tea plants are propagated from seed and cutting; it takes about 4 to 12 years for a tea plant to bear seed, and about three years before a new plant is ready for harvesting. In addition to a zone 8 climate or warmer, tea plants require at least 127 cm (50 inches) of rainfall a year and prefer acidic lands. Many high-quality tea plants are cultivated at elevations of up to 1,500 m (4,900 ft) above sea level. While at these heights the plants grow more slowly, they acquire a better flavor.

Two principal varieties are used: *Camellia sinensis* var. *sinensis*, which is used for most Chinese, Formosan and Japanese teas, and *Camellia sinensis* var. *assamica*, used in Pu-erh and most Indian teas (but not Darjeeling). Within these botanical varieties, there are many strains and modern clonal varieties. Leaf size is the chief criterion for the categorization of tea plants, with three primary categorizations being, Assam type, characterized by the large leaves; China type, characterized by the smallest leaves; Cambodian type, characterized by leaves of intermediate size.

A tea plant will grow into a tree of up to 16 m (52 ft) if left undisturbed, but cultivated plants are generally pruned to waist height for ease of plucking. Also, the short plants bear more new shoots which provide new and tender leaves and increase the quality of the tea.

Only the top 1–2 inches of the mature plant are picked. These buds and leaves are called *flushes*. A plant will grow a new flush every seven to fifteen days during the growing season. Leaves that are slow in development tend to produce better-flavored teas. Pests of tea include mosquito bugs that can tatter leaf, so they may be sprayed with insecticides.

Organic tea cultivation is endorsed by governments, corporations, and foundations in tea-growing countries, due to the danger of insecticides to human health and the potential for land pollution. Naturally occurring mined products are used for land fertilization. Leaf pests and diseases are controlled with the use of biological control agents, which are prepared or extracted without the use of chemical solvents.

2.4.4.2 Processing and categorization

Teas can generally be divided into categories based on how they are processed. There are at least six different types of tea: white, yellow, green, Oolong (or *Wulong*), black (called *red tea* in China), and post-fermented tea (or *black tea* for the Chinese) of which the most commonly found on the market are white, green, Oolong, and black. Some varieties, such as traditional Oolong tea and Pu-erh tea, a post-fermented tea, can be used medicinally.

After picking, the leaves of *C. sinensis* soon begin to wilt and oxidize, unless they are immediately dried. The leaves turn progressively darker as their chlorophyll breaks down and tannins are released. This enzymatic oxidation process, known as fermentation in the tea industry, is caused by the plant intracellular enzymes and causes the tea to darken. In tea processing, the darkening is stopped at a predetermined stage by heating, which deactivates the enzymes responsible. In the production of black teas, the halting of oxidation by heating is carried out simultaneously with drying.

Without careful moisture and temperature control during manufacture and packaging, the tea may become unfit for consumption, due to the growth of undesired molds and bacteria.

2.4.4.2 Blending and additives

Although single-estate teas are available, almost all teas in bags and most other teas sold in the West are now blends. Tea may be blended with other teas from the same area of cultivation or with teas from several different areas. The aim of blending is to obtain a better taste, a higher price, or both, as a more expensive, better-tasting tea is sometimes used to cover the inferior taste of cheaper varieties.

Some commercial teas have been enhanced through additives or special processing. Tea easily retains odors, which can cause problems in processing, transportation, and storage but also allows for the design of an almost endless range of scented and flavored variants, such as bergamot (Earl Grey), vanilla, and caramel.

2.4.4.3 Content

Tea contains catechins, a type of antioxidant. In a freshly picked tea leaf, catechins can comprise up to 30% of the dry weight. Catechins are highest in concentration in white and green teas, while black tea has substantially less due to its oxidative preparation. Research by the U.S. Department of Agriculture has suggested that the levels of antioxidants in green and black teas do not differ greatly, as green tea has an oxygen radical absorbance capacity (ORAC) of 1253 and black tea an ORAC of 1128 (measured in μmol TE/100 g). Antioxidant content, measured by the lag time for oxidation of cholesterol, is improved by cold-water steeping of varieties of tea.

Tea also contains the amino acid L-theanine which modulates caffeine's psychoactive effect and contributes to tea's umami taste. Caffeine constitutes about 3% of tea's dry weight, translating to between 30 mg and 90 mg per 8-Oz (250-ml) cup depending on type, brand, and brewing method.

Tea also contains small amounts of theobromine and theophylline, which are stimulants and xanthines similar to caffeine.

Because of modern environmental pollution, fluoride and aluminium also sometimes occur in tea, certain types of brick tea made from old leaves and stems having the highest levels.

Although tea contains various polyphenols and tannins, it does not contain tannic acid.

Review Questions

1. Define the Mineral Resources?
2. Explain the Power Resources?
3. Explain the Resource Conservation?
4. Explain the Principal Crops?

Discussion Questions

Discuss the importance of wheat, rice, sugarcane and tea?

Chapter 3- Theory of Agriculture

Learning Objectives

- To define the Agricultural Regions of the World.
- To explain the Theory of Agricultural Location.
- To explain the Industrial Location.
- To describe the Major Industries.

3.1 Agricultural Regions of the World (Derwent Whittlesey)

One of the most satisfactory categorization of agricultural regions in the world was proposed by D. Whittlesey in 1936. Whittlesey employed five criteria to classify agricultural regions in the world: (a) crop and livestock combination; (b) intensity of land use; (c) processing and marketing of farm produce; (d) degree of mechanization; and (e) types and associations of buildings and other structures associated with agriculture.

Based on these criteria, the following 13 main types of agricultural regions have been identified: (1) nomadic herding; (ii) livestock ranching; (iii) shifting cultivation; (iv) rudimental sedentary tillage; (v) intensive subsistence, ricedominant; (vi) intensive subsistence, without rice; (vii) commercial plantation; (viii) Mediterranean agriculture; (ix) commercial grain farming; (x) commercial livestock and crop farming; (xi) Subsistence crop and livestock farming; (xii) commercial dairy farming; and (xiii) specialized horticulture.

3.2 Theory of Agricultural Place (Von Thunen).

The Von Thunen model of agricultural land use was created by farmers and amateur economist J.H. Von Thunen (1783-1850) in 1826 (but it wasn't translated into English until 1966). Von Thunen's model was created before industrialization and is based on the following limiting assumptions:

- The city is located centrally within an "Isolated State" which is self sufficient and has no external influences.
- The Isolated State is surrounded by an unoccupied wilderness.
- The land of the State is completely flat and has no rivers or mountains to interrupt the terrain.
- The land quality and climate are consistent throughout the State.
- Farmers in the Isolated State transport their own goods to market via oxcart, across land, directly to the central city. Therefore, there are no roads.
- Farmers act to maximize profits.

In an Isolated State with the foregoing statements being true, Von Thunen hypothesized that a pattern of rings around the city would develop.

There are four rings of agricultural activity surrounding the city. Dairying and intensive farming occur in the ring closest to the city. Since vegetables, fruit, milk and other dairy products must get to market quickly, they would be produced closer to the city (remember, we didn't have refrigerated ox carts!)

Timber and firewood would be produced for fuel and building materials in the second zone. Before industrialization (and coal power), wood was a very important fuel for heating and cooking. Wood is very heavy and difficult to transport so it is located as close to the city as possible.

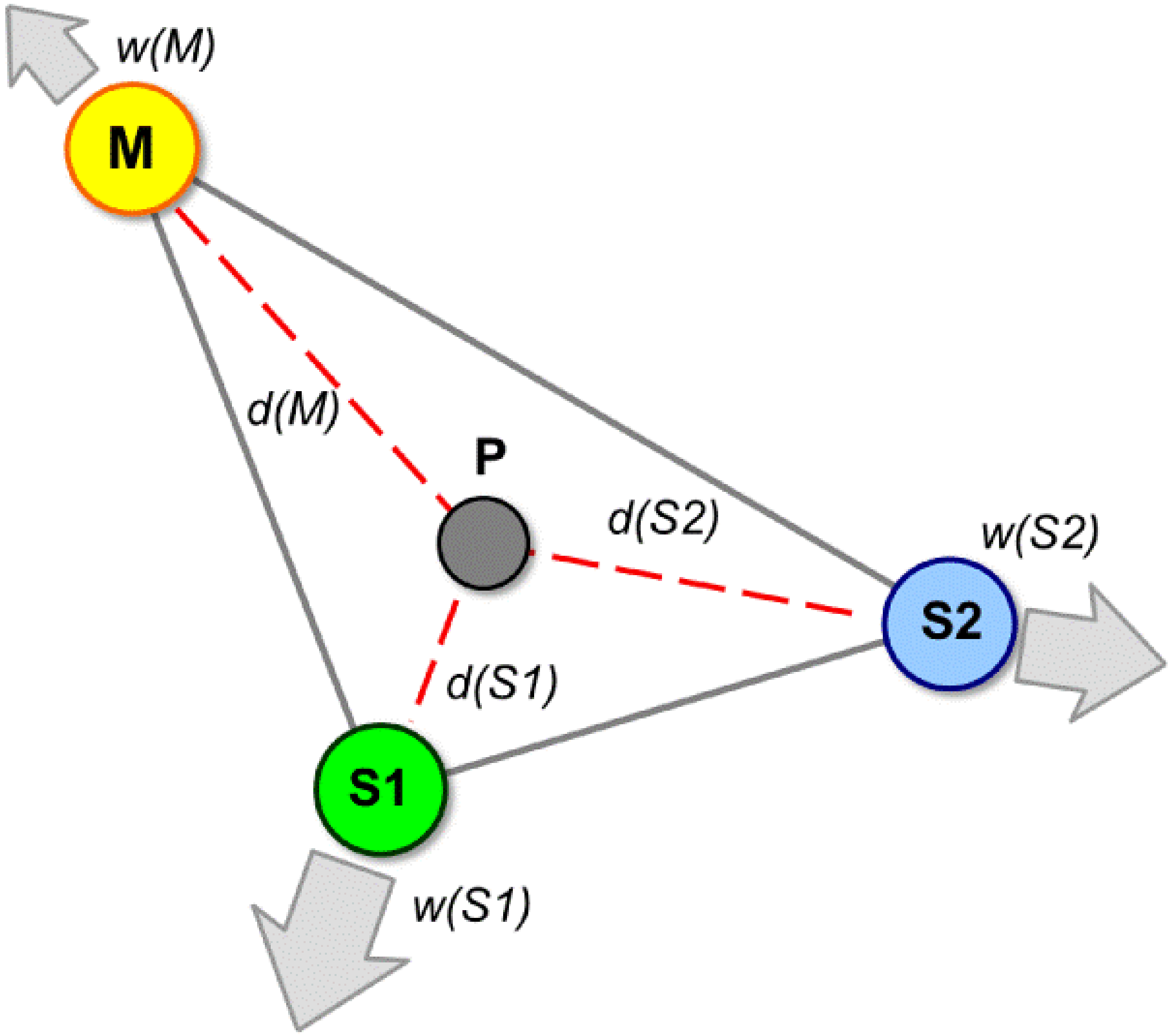
The third zone consists of extensive field crops such as grains for bread. Since grains last longer than dairy products and are much lighter than fuel, reducing transport costs, they can be located further from the city.

Ranching is located in the final ring surrounding the central city. Animals can be raised far from the city because they are self-transporting. Animals can walk to the central city for sale or for butchering.

Beyond the fourth ring lies the unoccupied wilderness, which is too great a distance from the central city for any type of agricultural product.

Even though the Von Thunen model was created in a time before factories, highways, and even railroads, it is still an important model in geography. The Von Thunen model is an excellent illustration of the balance between land cost and transportation costs. As one gets closer to a city, the price of land increases. The farmers of the Isolated State balance the cost of transportation, land, and profit and produce the most cost-effective product for market. Of course, in the real world, things don't happen as they would in a model.

3.3 Theory of Industrial Location



Weber's Place Triangle Alfred Weber's work (1909) is considered to have established the foundations of modern place theories. One of his core assumption is that firms will chose a place in view to minimize their costs. This involves a set of simplifications, namely that place takes place in an isolated region (no external influences) composed of one market, that space is isotropic (no variations in transport costs except a simple function of distance) and that markets are located in a specific number of centers. Those conditions are quite similar to those behind Von Thunen's agricultural land use model elaborated almost one hundred years earlier. The model also assumes perfect competition, implying a high number of firms and customers, small firm sizes (to prevent disruptions created by monopolies and oligopolies) and a perfect knowledge of market conditions, both for the buyers and suppliers. Several natural resources such are water are ubiquitous (available everywhere) while many production inputs such as labor, fuel and minerals are available at specific places. According to Weber, three main factors influence industrial place; transport costs, labor costs and agglomeration economies. Place thus imply an optimal consideration of these factors. Solving Weber's place model often implies three stages; finding the least transport cost place and adjusting this place to consider labor costs and agglomeration economies. Transportation is the most important element of the model since other factors are considered to only have an adjustment effect. To solve this problem, Weber uses the **place triangle** within which the optimal is located. Considering a product of w (M) tons to be sold at market M, w (S1) and w (S2) tons of materials coming respectively from S1 and S2 are necessary. The problem resides in finding an optimal factory place P located at the respective distances of d (M), d (S1) and d (S2). Several methodologies can be used to solve this problem such as drawing an analogy to a system of weights and pulleys (Varignon's solution) or using trigonometry. Another way preferred among geographers, particularly with GIS, is to use **cost surfaces** which are overlaid. Weber's place theory explains well the place of heavy industries, particularly from the industrial revolution until the mid twentieth century (the sector that Weber was looking at). Actions having a high level of use of raw materials tend to locate near supply sources, such as aluminum factories will locate near energy sources (electricity) or port sites. Actions using ubiquitous raw materials, such as water, tend to locate close to markets. To assess this issue, Weber developed a **material index** which is simply the weight of the inputs divided by the weight of the final product (output). If the material index is higher than 1, place tends to be toward material sources. If it is less than 1, place tends to be toward the market. Contemporary developments in manufacturing, the reduction of transport costs and new economic sectors (high technology) have changed placeal behavior substantially, involving much less consideration to Weber's principles. Still, these principles apply well for industries with a very high material index.

3.4 Major Industries: Iron &Steel, Textiles, Petro - Chemical & Sugar.

3.4.1 Iron & Steel

It is common today to talk about "the iron and steel industry" as if it was a single entity, but historically they were separate products. The steel industry is often considered an indicator of economic progress, because of the critical role played by steel in infrastructural and overall economic development.

In 1980, there were more than 500,000 U.S. steelworkers. By 2000, the number of steelworkers fell to 224,000.

The economic boom in China and India has caused a massive increase in the demand for steel in recent years. Between 2000 and 2005, world steel demand increased by 6%. Since 2000, several Indian and Chinese steel firms have risen to prominence like Tata Steel (which bought Corus Group in 2007), Shanghai Baosteel Group Corporation and Shagang Group. ArcelorMittal is however the world's largest steel producer.

In 2005, the British Geological Survey stated China was the top steel producer with about one-third of the world share; Japan, Russia, and the US followed respectively.

In 2008, steel began trading as a commodity on the London Metal Exchange. At the end of 2008, the steel industry faced a sharp downturn that led to many cutbacks.

The world steel industry peaked in 2007. That year, ThyssenKrupp spent $12 billion to build the two most modern mills in the world, in Calvert, Alabama and Sepetiba, Rio de Janeiro, Brazil. The worldwide Great Recession starting in 2008, however, sharply lowered demand and new construction, and so prices fell. ThyssenKrupp lost $11 billion on its two new plants, which sold steel below the cost of production. Finally in 2013, ThyssenKrupp offered the plants for sale at under $4 billion.

3.4.2 **Textile industry**

The **textile industry** or **apparel industry** is primarily concerned with the production of yarn, and cloth and the subsequent design or manufacture of clothing and their distribution . The raw material may be natural, or synthetic using products of the chemical industry.

3.4.2.1 **Cotton manufacturing**

Cotton is the world's most important natural fiber. In the year 2007, the global yield was 25 million tons from 35 million hectares cultivated in more than 50 countries. There are five stages

- Cultivating and Harvesting
- Preparatory Processes
- Spinning- giving yarn
- Weaving- giving fabrics
- Finishing- giving textiles

3.4.2.2 **Synthetic fibers**

Artificial fibers can be made by extruding a polymer, through a spinneret into a medium where it hardens. Wet spinning (rayon) uses a coagulating medium. In the dry spinning (acetate and triacetate), the polymer is contained in a solvent that evaporates in the heated exit chamber. In melt spinning (nylons and polyesters) the extruded polymer is cooled in gas or air and then sets. All these fibers will be of great length, often kilometers long.

Artificial fibers can be processed as long fibers or batched and cut so they can be processed like a natural fiber.

3.4.2.3 **Natural fibers**

Natural fibers are either from animals (sheep, goat, rabbit, silk-worm) mineral (asbestos) or from plants (cotton, flax, sisal). These vegetable fibers can come from the seed (cotton), the stem (known as bast fibers: flax, Hemp, Jute) or the leaf (sisal). Without exception, many processes are needed before a clean even staple is obtained- each with a specific name. With the exception of silk, each of these fibers is short being only centimeters in length, and each has a rough surface that enables it to bond with similar staples.

3.4.2.4 **History**

3.4.2.4.1 **Cottage stage**

There are some indications that weaving was already known in the Palaeolithic. An indistinct textile impression has been found at Pavlov, Moravia. Neolithic textiles are well known from finds in pile dwellings in Switzerland. One extant fragment from the Neolithic was found in Fayum at a site which dates to about 5000 BC.

The key British industry at the beginning of the 18th century was the production of textiles made with wool from the large sheep-farming areas in the Midlands and across the country (created as a result of land-clearance and enclosure). This was a labor-intensive activity providing employment throughout Britain, with major centers being the West Country; Norwich and environs; and the West Riding of

Yorkshire. The export trade in woolen goods accounted for more than a quarter of British exports during most of the 18th century, doubling between 1701 and 1770. Exports of the cotton industry – centered in Lancashire – had grown tenfold during this time, but still accounted for only a tenth of the value of the woolen trade. Before the 17th century, the manufacture of goods was performed on a limited scale by individual workers. This was usually on their own premises (such as weavers' cottages) – and goods were transported around the country. Clothiers visited the village with their trains of pack-horses. Some of the cloth was made into clothes for people living in the same area, and a large amount of cloth was exported. Rivers navigations were constructed, and some contour-following canals. In the early 18th century, artisans were inventing ways to become more productive. Silk, wool, fustian, and linen were being eclipsed by cotton, which was becoming the most important textile. This set the foundations for the changes.

In Roman times, wool, linen and leather clothed the European population, and silk, imported along the Silk Road from China, was an extravagant luxury. The use of flax fiber in the manufacturing of cloth in Northern Europe dates back to Neolithic times.

During the late medieval period, cotton began to be imported into northern Europe. Without any knowledge of what it came from, other than that it was a plant, noting its similarities to wool, people in the region could only imagine that cotton must be produced by plant-borne sheep. John Mandeville, writing in 1350, stated as fact the now-preposterous belief: "There grew in India a wonderful tree which bore tiny lambs on the ends of its branches. These branches were so pliable that they bent down to allow the lambs to feed when they are hungry." This aspect is retained in the name for cotton in many European languages, such as German*Baumwolle*, which translates as "tree wool". By the end of the 16th century, cotton was cultivated throughout the warmer regions of Asia and the Americas.

The main steps in the production of cloth are producing the fiber, preparing it, converting it to yarn, converting yarn to cloth, and then finishing the cloth. The cloth is then taken to the manufacturer of garments. The preparation of the fibers differs the most, depending on the fiber used. Flax requires retting and dressing, while wool requires carding and washing. The spinning and weaving processes are very similar between fibers, however.

Spinning evolved from twisting the fibers by hand, to using a drop spindle, to using a spinning wheel. Spindles or parts of them have been found in archaeological sites and may represent one of the first pieces of technology available. They were invented in India between 500 and 1000 AD.

3.4.2.4.2 **Industrial revolution**

The textile industry grew out of the industrial revolution in the 18th Century as mass production of yarn and cloth became a mainstream industry.

In 1734 in Bury, Lancashire, John Kay invented the flying shuttle — one of the first of a series of inventions associated with the cotton industry. The flying shuttle increased the width of cotton cloth and speed of production of a single weaver at a loom. Resistance by workers to the perceived threat to jobs delayed the widespread introduction of this technology, even though the higher rate of production generated an increased demand for spun cotton.

In 1761, the Duke of Bridgewater's canal connected Manchester to the coal fields of Worsley and in 1762, Matthew Boulton opened the Soho Foundry engineering works in Handsworth, Birmingham. His partnership with Scottish engineer James Watt resulted, in 1775, in the commercial production of the more efficient Watt steam engine which used a separate condenser.

In 1764, James Hargreaves is credited as the inventor of the spinning jenny which multiplied the spun thread production capacity of a single worker — initially eightfold and subsequently much further. Others credit the original invention to Thomas Highs. Industrial unrest and a failure to patent the invention until 1770 forced Hargreaves from Blackburn, but his lack of protection of the idea allowed the idea to be exploited by others. As a result, there were over 20,000 Spinning Jennies in use by the time of his death. Again in 1764, Thorp Mill, the first water-powered cotton mill in the world was constructed at Royton, Lancashire, England. It was used for carding cotton. With the spinning and weaving process now mechanized, cotton mills cropped up all over the North West of England.

3.4.2.4.3 **19th century developments**

With the Cartwright Loom, the Spinning Mule and the Boulton& Watt steam engine, the pieces were in place to build a mechanized textile industry. From this point there were no new inventions, but a continuous improvement in technology as the mill-owner strove to reduce cost and improve quality. Developments in the transport infrastructure; that is the canals and after 1831 the railways facilitated the import of raw materials and export of finished cloth.

Firstly, the use of water power to drive mills was supplemented by steam driven water pumps, and then superseded completely by the steam engines. For example Samuel Greg joined his uncle's firm of textile merchants, and, on taking over the company in 1782, he sought out a site to establish a mill. Quarry Bank Mill was built on the River Bollin at Styal in Cheshire. It was initially powered by a water wheel, but installed steam engines in 1810.Quarry Bank Mill in Cheshire still exists as a well preserved museum, having been in use from its construction in 1784 until 1959. It also illustrates how the mill owners exploited child labor, taking orphans from nearby Manchester to work the cotton. It shows that these children were housed, clothed, fed and provided with some education. In 1830, the average power of a mill engine was 48 hp, but Quarry Bank mill installed a new 100 hp water wheel. William Fairbairn addressed the problem of line-shafting and was responsible for improving the efficiency of the mill. In 1815 he replaced the wooden turning shafts that drove the machines at 50rpm, to wrought iron shafting working at 250 rpm, these were a third of the weight of the previous ones and absorbed less power.

Secondly, in 1830, using a 1822 patent, Richard Roberts manufactured the first loom with a cast iron frame, the Roberts Loom. In 1842 James Bullough and William Kenworthy, made the Lancashire Loom . It is a semi automatic power loom. Although it is self-acting, it has to be stopped to recharge empty shuttles. It was the mainstay of the Lancashire cotton industry for a century, when the [Originally, power looms were shuttle-operated but in the early part of the 20th century the faster and more efficient shuttleless loom came into use. Today, advances in technology have produced a variety of looms designed to maximize production for specific types of material. The most common of these are air-jet looms and water-jet looms. Industrial looms can weave at speeds of six rows per second and faster.

Thirdly, also in 1830, Richard Roberts patented the first self-acting mule. Stalybridge mule spinners strike was in 1824, this stimulated research into the problem of applying power to the winding stroke of the mule. The draw while spinning had been assisted by power, but the push of the wind had been done manually by the spinner, the mule could be operated by semi-skilled labor. Before 1830, the spinner would operate a partially powered mule with a maximum of 400 spindles after, self-acting mules with up to 1300 spindles could be built.

The industrial revolution changed the nature of work and society The three key drivers in these changes were textile manufacturing, iron founding and steam power. The geographical focus of textile manufacture in Britain was Manchester, England and the small towns of the Pennines and southern Lancashire.

Textile production in England peaked in 1926, and as mills were decommissioned, many of the scrapped mules and looms were bought up and reinstated in India. The demographic change made by World War I, had made the labor-intensive industry unprofitable in England, but in India and later China it was an aid to development.

3.4.2.4.4 **20th century**

Major changes came to the textile industry during the 20th century, with continuing technological innovations in machinery, synthetic fiber, logistics, and globalization of the business. The business model that had dominated the industry for centuries was to change radically. Cotton and wool producers were not the only source for fires, as chemical companies created new synthetic fibers that had superior qualities for many uses, such as rayon, invented in 1910, and DuPont's nylon, invented in 1935 as in inexpensive silk substitute, and used for products ranging from women's stockings to tooth brushes and military parachutes.

The variety of synthetic fibers used in manufacturing fiber grew steadily throughout the 20th century. In the 1920s, acetate was invented; in the 1940s, acetate, modacrylic, metal fibers, and saran were developed; acrylic, polyester, and spandex were introduced in the 1950s. Polyester became hugely popular in the apparel market, and by the late 1970s, more polyester was sold in the United States than cotton.

By the early 20th century, the industry in the developed world often involved immigrants in "sweat shops", which were usually legal but were sometimes illegally operated. They employed people in crowded conditions, working manual sewing machines, and being paid less than a living wage. This trend worsened due to attempts to protect existing industries which were being challenged by developing countries in South East Asia, the Indian subcontinent and Central America. Although globalization saw the manufacturing largely outsourced to overseas labor markets, there has been a trend for the areas historically associated with the trade to shift focus to the more white collar associated industries of fashion design, fashion modeling and retail. Areas historically involved heavily in the "rag trade" include London and Milan in Europe, and the SoHo district in New York City.

By the late 1980s, the apparel segment was no longer the largest market for fiber products, with industrial and home furnishings together representing a larger proportion of the fiber market. Industry integration and global manufacturing led to many small firms closing for good during the 1970s and 1980s in the United States; during those decades, 95 percent of the loom in North Carolina, South Carolina and Georgia shut down, and Alabama and Virginia also saw many factories close.

3.4.2.4.5 **21st century**

In 2002, textiles and apparel manufacturing accounted for $400 billion in global exports, representing 6% of world trade and 8% of world trade in manufactured goods. In the early years of the 21st century, the largest importing and exporting countries were developed countries, including the European Union, the United States, Canada and Japan. The countries with the largest share of their exports being textiles and apparel were as follows (2002):

- Bangladesh: 85.9%
- Macau: 84.4%
- Cambodia: 72.5%
- Pakistan: 72.1%
- El Salvador: 60.2%

- Mauritius: 56.6%
- Sri Lanka: 54.3%
- Dominican Republic: 50.9%
- Nepal: 48.7%
- Tunisia: 42.4%

3.4.3 Petro chemicals

The world petrochemical industry has changed drastically in the last twenty to thirty years. The United States, Western Europe and Japan previously dominated production of primary petrochemicals, not only to supply their own domestic demand but also to export to other world markets. These areas accounted for over 80% of world primary petrochemical production prior to 1980. However, world-scale construction of petrochemical facilities in other parts of the world has been on the rise. Countries with vast reserves of crude oil and natural gas (e.g., Saudi Arabia and Canada) have constructed plants to add value to their resources. Since these countries generally have smaller domestic demand, a significant share of petrochemical production is earmarked for the export market. Other countries, such as Singapore, the Republic of Korea, and Taiwan, expanded capacity during the past two decades to support growing economies and for exports to other regions that have limited capacity. Still other countries were driven by the desire for self-sufficiency because of their rapidly growing populations (e.g., Thailand, Malaysia, Indonesia and China). The start-up of these plants has effectively diminished the number of export markets available to the United States, Western Europe and Japan as the volume of imports from developing regions increased. As a consequence, the petrochemical industries in the United States, Western Europe and Japan have experienced lower growth rates. In 2010, these three regions accounted for only 37% of world primary petrochemicals production.

Fossil fuels—coal, crude oil or petroleum, natural gas liquids, and natural gas—are the primary sources of basic petrochemicals. The most important use of fossil fuels is in the production of energy. In 2010, annual world energy production from fossil fuels, hydroelectric power and nuclear power amounted to 433 quadrillion British thermal units (Btus). Of this total, 67% or 290 quadrillion Btus came from crude oil, coal, natural gas and natural gas liquids. The fraction of fossil fuel energy equivalents diverted to primary petrochemical production was an estimated 17 quadrillion Btus or 5–7% of the total consumed. Although only a small subset of world energy demand, petrochemical prices are heavily influenced by fluctuations in the world energy market.

In the petrochemical industry, the organic chemicals with the largest production volume are methanol, ethylene, propylene, butadiene, benzene, toluene and xylenes. Ethylene, propylene and butadiene, along with butylenes, are collectively called *olefins*, which belong to a class of unsaturated aliphatic hydrocarbons having the general formula CnH2n. Olefins contain one or more double bonds, which make them chemically reactive. Benzene, toluene and xylenes are commonly referred to as *aromatic*, which are unsaturated cyclic hydrocarbons containing one or more rings. Olefins, aromatics and methanol are precursors to a variety of chemical products and are generally referred to as *primary petrochemicals*.

3.4.4 Sugar

Sugar is the generalized name for a class of chemically-related sweet-flavored substances, most of which are used as food. They are carbohydrates, composed of carbon, hydrogen and oxygen. There are various types of sugar derived from different sources. Simple sugars are called monosaccharides and include glucose (also known as dextrose), fructose and galactose. The table or granulated sugar most customarily used as food is sucrose, a disaccharide (in the body, sucrose hydrolysis into fructose and glucose). Other disaccharides include maltose and lactose. Chemically-different substances may also have a sweet taste, but are not classified as sugars. Some are used as low-calorie food substitutes for sugar described as artificial sweeteners.

Sugars are found in the tissues of most plants, but are only present in sufficient concentrations for efficient extraction in sugar cane and sugar beet. Sugar cane is a giant grass and has been cultivated in tropical climates in the Far East since ancient times. A great expansion in its production took place in the 18th century with the lay out of sugar plantations in the West Indies and Americas. This was the first time that sugar became available to the common people who previously had to rely on honey to sweeten foods. Sugar beet is a root crop, is cultivated in cooler climates, and became a major source of sugar in the 19th century when methods for extracting the sugar became available. Sugar production and trade have changed the course of human history in many ways. It influenced the formation of colonies, the perpetuation of slavery, the transition to indentured Labor, the migration of peoples, wars between sugar trade-controlling nations in the 19th century, and the ethnic composition and political structure of the new world.

The world produced about 168 million tonnes of sugar in 2011. The average person consumes about 24 kilograms of sugar each year (33.1 kg in industrialized countries), equivalent to over 260 food calories per person, per day.

3.4.4.1 **Types of sugar**

3.4.4.1.1 **Monosaccharides**

Glucose, fructose and galactose are all simple sugars, monosaccharides, with the general formula $C_6H_{12}O_6$. They have five hydroxyl groups (−OH) and a carbonyl group (C=O) and are cyclic when dissolved in water. They each exist as several isomers with Dextro- and laevo-rotatory forms which cause polarized light to diverge to the right or the left.

Glucose, dextrose or grape sugar occurs naturally in fruits and plant juices and is the primary product of photosynthesis. Most ingested carbohydrates are converted into glucose during digestion and it is the form of sugar that is transported around the bodies of animals in the bloodstream. It can be manufactured from starch by the addition of enzymes or in the presence of acids. Glucose syrup is a liquid form of glucose that is widely used in the manufacture of foodstuffs. It can be manufactured from starch by enzymatic hydrolysis.

Fructose or fruit sugar occurs naturally in fruits, some root vegetables, cane sugar and honey and is the sweetest of the sugars. It is one of the components of sucrose or table sugar. It is used as a high fructose syrup which is manufactured from hydrolyzed cornstarch which has been processed to yield corn syrup, with enzymes then added to convert part of the glucose into fructose.

Galactose does not generally occur in the free state but is a constituent with the glucose of the disaccharide lactose or milk sugar. It is less sweet than glucose. It is a component of the antigens found on the surface of red blood cells that determine blood groups.

3.4.4.1.2 **Disaccharides**

Sucrose, maltose and lactose are all compound sugars, disaccharides, with the general formula $C_{12}H_{22}O_{11}$. They are formed by the combination of two monosaccharide molecules with the exclusion of a molecule of water.

Sucrose is found in the stems of sugar cane and roots of sugar beet. It also occurs naturally alongside fructose and glucose in other plants, particularly fruits and some roots such as carrots. The different proportions of sugars found in these foods determine the range of sweetness experienced when eating them. A molecule of sucrose is formed by the combination of a molecule of glucose with a molecule of fructose. After being eaten, sucrose is split into its constituent parts during digestion by a number of enzymes known as sucrose.

Maltose is formed during the germination of certain grains, most notably barley which is converted into malt, the source of the sugar's name. A molecule of maltose is formed by the combination of two molecules of glucose. It is less sweet than glucose, fructose or sucrose. It is formed in the body during the digestion of starch by the enzyme amylase and is itself broken down during digestion by the enzyme maltase.

Lactose is the naturally occurring sugar found in milk. A molecule of lactose is formed by the combination of a molecule of galactose with a molecule of glucose. It is broken down when consumed into its constituent parts by the enzyme lactose during digestion. Children have this enzyme but some adults no longer form it and they are unable to digest lactose.

3.4.4.2 **Production**

3.4.4.2.1 **Sugar beet**

Sugar beet (*Beta vulgaris*) is an annual plant in the FamilyAmaranthaceae, the tuberous root of which contains a high proportion of sucrose. It is cultivated in temperate regions with adequate rainfall and requires a fertile land. The crop is harvested mechanically in the autumn and the crown of leaves and excess land removed. The roots do not deteriorate rapidly and may be left in a clamp in the field for some weeks before being transported to the processing plant. Here the crop is washed and sliced and the sugar extracted by diffusion. Milk of lime is added to the raw juice and carbonated in a number of stages in order to purify it. Water is evaporated by boiling the syrup under a vacuum. The syrup is then cooled and seeded with sugar crystals. The white sugar which crystallizes out can be separated in a centrifuge and dried. It requires no further refining.

3.4.4.2.2 **Refining**

Cane sugar requires further processing to provide the free-flowing white table sugar required by the consumer. The sugar may be transported in bulk to the country where it will be used and the refining process often takes place there. The first stage is known as affination and involves immersing the sugar crystals in a concentrated syrup which softens and removes the sticky brown coating without dissolving them. The crystals are then separated from the liquor and dissolved in water. The resulting syrup is either treated by a carbonation or a phosphatation process. Both involve the precipitation of a fine solid in the syrup and when this is filtered out, a lot of the impurities are removed at the same time. Removal of color is achieved by either using a granular activated carbon or an ion-exchange resin. The sugar syrup is concentrated by boiling and then cooled and seeded with sugar crystals causing the sugar to crystallize out. The liquor is spun in a centrifuge and the white crystals are dried in hot air, ready to be packaged or used. The surplus liquor is made into refiners' molasses. The International Commission for Uniform

Methods of Sugar Study sets standards for the measurement of the purity of refined sugar, known as ICUMSA numbers; lower numbers indicate a higher level of purity in the refined sugar.

3.4.4.3 **Producing countries**

The five largest producers of sugar in 2011 were Brazil, India, the European Union, China and Thailand. In the same year, the largest exporter of sugar was Brazil, distantly followed by Thailand, Australia and India. The largest importers were the European Union, United States and Indonesia. Currently, Brazil has the highest per capita consumption of sugar, followed by Australia, Thailand and the European Union.

World sugar production (1000 metric tons)

Country	**2007/08**	**2008/09**	**2009/10**	**2010/11**	**2011/12**
Brazil	31,600	31,850	36,400	38,350	35,750
India	28,630	15,950	20,637	26,650	28,300
European Union	15,614	14,014	16,687	15,090	16,740
China	15,898	13,317	11,429	11,199	11,840
Thailand	7,820	7,200	6,930	9,663	10,170
United States	7,396	6,833	7,224	7,110	7,153
Mexico	5,852	5,260	5,115	5,495	5,650
Russia	3,200	3,481	3,444	2,996	4,800
Pakistan	4,163	3,512	3,420	3,920	4,220
Australia	4,939	4,814	4,700	3,700	4,150
Other	38,424	37,913	37,701	37,264	39,474
Total	**163,536**	**144,144**	**153,687**	**161,437**	**168,247**

3.5 Industrial Regions of the World

The future of the world is today being shaped by industrialization. The remarkable achievements that began in a single nation have not yet been shared equally by all humanity but this may be about to change. Modern industry is largely a phenomenon of countries in the mid-latitudes of the Northern Hemisphere with few peripheral countries as yet members of this rather exclusive club. As the world approaches the twenty-first century much has changed concerning industrialization and the resources that support it. The industry is presently undergoing a global shift which portends a new era for the world as we have come to know it.

When the Bolsheviks took control of the Russian Empire, they found themselves in charge of a vast realm with a mainly agricultural economy. There was nothing in the Soviet Union of the 1920s to rival what was happening in Europe or North America. Soviet communist rulers were determined to change this. They wanted to transform the Soviet economy into an industrial one. The human cost of this gigantic scheme was dreadful, but the desired transformation was accomplished. The Soviet Union became a major industrial power with vast manufacturing complexes.

Outside the Soviet Union, industrial development took a very different course. Market forces, not state planning propelled the Industrial Revolution in Europe and North America, and industrial economies on both sides of the Atlantic Ocean rose to global prominence. Because of the imposition of Soviet ideology and economic planning in Eastern Europe's industrial development, for more than four decades after World War II, Eastern Europe's economic geography was constrained. Western Europe's industrial growth proceeded more freely, and in the postwar period Japan, Taiwan, and South Korea industrialized under free-enterprise rules as well. China, on the other hand, collectivized its agriculture and put it industries under state control.

3.5.1 Major Industrial Regions

Whatever the ideological basis (market-commercial, communist-state, or some combination), the world map of major regional-industrial development reveals that only a small minority of countries have become major industrial economies. Four major industrial regions have developed, all in the Northern Hemisphere:

Western and Central Europe, Eastern North America, Russia-Ukraine, and Eastern Asia. Each consists of core areas with subsidiary clusters some distance away.

While the older manufacturing regions are quite entrenched, notable shifts are occurring. This dispersal is especially evident in East Asia, where Japan's dominance is being challenged by the "Four Tigers" of East Asia. In addition, the entrance of China into the global manufacturing economy in the 1980s is certain to gain in significance in the twenty-first century.

3.5.1.1 Europe

The place of Europe's primary industrial regions still reflects the spatial diffusion of the Industrial Revolution. An axis of manufacturing extends from Britain to Poland and the Czech Republic, and onward to Ukraine. The explanation of this pattern lies in the place of coal fields in Britain and the European continent. Britain's coal fired industries produced a pattern of functional specialization that, for a time, had no equal in the world, for it was coal that fired the Industrial Revolution.

Europe's coal deposits lie in a belt across northern France, Belgium, north-central Germany, the northwestern Czech Republic, and southern Poland—and when the Industrial Revolution diffused from Britain onto the mainland it was along this zone that Europe's major concentrations of heavy industry developed. Europe's industrial success also depended on the skills of its labor force and the high degree of specialization achieved in various industrial zones.

3.5.1.2 North America

In North America, industrialization occurred first in the East. Served by a wide array of natural resources and supported by networks of natural as well as artificial transportation systems, remote from the destruction caused by wars in other industrial regions, and on the doorstep of the world's richest market, North American manufacturing developed rapidly. Today, this complex, anchored by the American Manufacturing Belt—from the northeastern seaboard to Iowa, and from the St. Lawrence Valley to the confluence of the Ohio and Mississippi Rivers—is the largest in the world.

3.5.1.3 Ukraine and Russia

The most important country detached from the Soviet Empire (after Russia itself) was Ukraine. In the new Europe, Ukraine would be the largest territorial state and one of the most populous. It was a major manufacturing center before the end of the nineteenth century, having been strongly affected by the Industrial Revolution. Coal from its Donetsk Easin (Donbas) and iron ore from the KrivoyRog reserve and later from Russia's Kursk Magnetic Anomaly allowed Ukraine to grow into one of the world's largest manufacturing complexes. Today, despite Ukraine's political separation from the former Soviet Union (and hence from Russia), Ukrainian and Russian industries are interdependent: Ukraine needs Russian fuels and Russia needs Ukrainian raw materials.

3.5.1.4 Industrial Region of Asia

3.5.1.4.1 China

Industrial regions of China are the most dominant industrial power of Asia with industrial agglomerations in Manchurian region, Yangtze region, North-china region, South China region, etc. with many manufacturing units producing steel, heavy chemical's textiles, paper, cement, automobiles, toys, etc.

3.5.1.4.2 Japan

Industrial region of Japan has several industrial cities producing steel's Pedro-chemical, cement, footwear. toys, etc. at Tokya-Yokohama region, Osaka - Kobe region, north Kyushu region.

3.5.1.4.3 India

Industrial regions of India are The Calcutta Conurbation, The Mumbai-Pune Industrial belt, Ahemadabad - Vadodara belt, Southern industrial regions with Chennai, Coimbatore, Bangalore industrial belt, Damodar Valley industrial belt, Northern regions with centers like Delhi, Ambala, Gaziabad, Mathura, etc.

Other major industrial regions include Allahadad, Varanasi, Hyderabad, Patiala, Jaipur, Bilaspur, Jullundhar, Meerut, Lucknow, Kanpur, etc.

Review Questions

1. Define the Agricultural Regions of the World?
2. Explain the Theory of Agricultural Location?
3. Explain the Major Industries?

4. Explain the Land Relations in Pre-British India?

Discussion Questions

What are the major Industrial Regions of the World?

Chapter 4- World Transportation

Learning Objectives

- To discuss the major transportation route.
- To explain the International Trade.
- To explain the Major Trade Blocks.
- To describe the Effect of Globalization on Developing Countries.

4.1 Major Transcontinental Railways, Sea & Air Routes

4.1.1 Major Transcontinental Railways

A **transcontinental railroad** is a contiguous network of railroadtrackage that crosses a continental land mass with terminals at different oceans or continental borders. Such networks can be via the tracks of either a single railroad, or over those owned or controlled by multiple railway companies along a continuous route. Although Europe is crisscrossed by railways, the railroads within Europe are usually not considered transcontinental, with the possible exception of the historic Orient Express.

Transcontinental railroads helped open up unpopulated interior regions of continents to exploration and settlement that would not otherwise have been feasible. In many cases they also formed the backbones of cross-country passenger and freight transportation networks.

In the United States of America, transcontinental railroads created a nationwide transportation network that united the country. This network replaced the wagon trains of previous decades and allowed for the transportation of larger quantities of goods over long distances. Construction of the Central Pacific Railroad and Union Pacific Railroad of the 1,928 mile "Pacific Railroad" link between Council Bluff, IA/Omaha, NE and the San Francisco Bay at Oakland, CA via Ogden, UT and Sacramento, CA is connected to the existing railroad network to the East Coast creating the world's first transcontinental railroad when it opened in 1869 was made possible by the Congress through the passage of Pacific Railroad Acts of 1862, 1864 and 1867.

4.1.1.1 North America

4.1.1.1.1 United States

A **transcontinental railroad** in the United States is any continuous rail line connecting a place on the U.S. Pacific coast with one or more of the railroads of the nation's eastern trunk line rail systems operating between the Missouri or Mississippi Rivers and the U.S. Atlantic coast. The first concrete plan for a transcontinental railroad in the United States was presented to Congress by Asa Whitney in 1845.

The world's First Transcontinental Railroad was built between 1863 and 1869 to join the eastern and western halves of the United States. Begun just preceding the American Civil War, its construction was considered to be one of the greatest American technological feats of the 19th century. Known as the "Pacific Railroad" when it opened, this served as a vital link for trade, commerce, and travel and opened up vast regions of the North American heartland for settlement. Shipping and commerce could thrive away from navigable watercourses for the first time since the beginning of the nation. Much of this line is currently used by the *California Zephyr*, although some parts were rerouted or abandoned.

The transcontinental railroad provided fast, safe, and cheap transportation. The fare for a one week trip from Omaha to San Francisco on an emigrant sleeping car was about $65 for an adult. It replaced most of the far slower and more hazardous stagecoach lines and wagon trains. The number of emigrants taking the Oregon and California Trail declined dramatically. The sale of the railroad land grant lands and the transport provided for timber and crops led to the rapid settling of the "Great American Desert".

The Union Pacific recruited laborers from Army veterans and Irish emigrants while most of the engineers were ex-Army men who had learned their trade keeping the trains running during the American Civil War.

The Central Pacific Railroad faced a labor shortage in the more sparsely-settled West. It recruited Cantoneselaborers in China, who did prodigious work building the line over and through the Sierra Nevada mountains and then across Nevada to their meeting in northern Utah.

- A motive for the Gadsden Purchase of land from Mexico in 1853 was to provide suitable terrain for a southern transcontinental railroad, since the topography of the southern portion of the existing Mexican Cession land was too mountainous. The Southern Pacific Railroad was completed in 1881.
- The Pacific Railroad Act of 1862 (based on an earlier bill in 1856) authorized land grants for new lines that would *"aid in the construction of a railroad and telegraph line from the Missouri river to the Pacific ocean"*.
- The rise of the "First Transcontinental Railroad" were joined on May 10, 1869, with the ceremonial driving of the "Last Spike" at Promontory Summit, Utah, after the track was laid over a 1,756-mile (2,826 km) gap between Sacramento and Omaha, Nebraska/Council Bluffs, Iowa in six years by the Union Pacific Railroad and Central Pacific Railroad. Although through train service was in operation as of that date, the road was not deemed to have been officially "completed" until November 6, 1869. (A physical connection between Omaha, Nebraska and the *statutory* Eastern terminus of the Pacific road at Council Bluffs, Iowa located immediately across the Missouri River was also not finally established until the opening of the UPRR railroad bridge across the river on March 25, 1873, prior to which transfers were made by ferry operated by the Council Bluffs & Nebraska Ferry Company.)
- In 1882, the Atchison, Topeka and Santa Fe Railway connected Atchison, Kansas with the Southern Pacific Railroad at Deming, New Mexico, thus completing a second link to Los Angeles. In 1885, the Atlantic and Pacific Railroad and the California Southern Railroad gave the Santa Fe its own link to Los Angeles.
- The Southern Pacific Railroad linked New Orleans to Los Angeles in 1883, linking the Gulf of Mexico with the Pacific Ocean.
- The Northern Pacific Railway, also completed in 1883, linked Chicago to Seattle.
- The Great Northern Railway was built, without federal aid, by James J. Hill in 1893; it stretched from St. Paul to Seattle.
- In 1909 the Chicago, Milwaukee & St. Paul (or Milwaukee Road) completed a privately built Pacific extension to Seattle. On completion the line was renamed the Chicago, Milwaukee, St. Paul and Pacific. Although the Pacific Extension was privately funded, predecessor roads did benefit from the federal land grant act, so it cannot be said to have been built without federal aid.
- John D. Spreckels completed his privately funded San Diego and Arizona Railway in 1919, thereby creating a direct link (via connection with the Southern Pacific lines) between San Diego,

California and the Eastern United States. The railroad stretched 148 miles (238 km) from San Diego to Calexico, California.
- In 1993 Amtrak's *Sunset Limited* daily railroad train was extended eastward to the Atlantic Ocean, making it the first transcontinental passenger train route in the United States to be operated by a single company. Hurricane Katrina cut this rail route in Louisiana in 2005. The train now runs Los Angeles to New Orleans.

George J. Gould attempted to assemble a truly transcontinental system in the 1900s. The line from San Francisco, California, to Toledo, Ohio, was completed in 1909, consisting of the Western Pacific Railway, Denver and Rio Grande Railroad, Missouri Pacific Railroad, and the Wabash Railroad. Beyond Toledo, the planned route would have used the Wheeling and Lake Erie Railroad (1900), Wabash Pittsburgh Terminal Railway, Little Kanawha Railroad, West Virginia Central and Pittsburgh Railway, Western Maryland Railroad and Philadelphia and Western Railway, but the Panic of 1907 strangled the plans before the Little Kanawha section in West Virginia could be finished. The Alphabet Route was completed in 1931, providing the portion of this line east of the Mississippi River. With the merging of the railroads, only the Union Pacific Railroad and the BNSF Railway remain to carry the entire route.

4.1.1.2 **Canada**

The completion of Canada's first transcontinental railroad, on November 7, 1885 is an important milestone in Canadian history. Between 1881 and 1885, the Canadian Pacific Railway (CPR) completed a line that spanned from the port of Montreal to the Pacific coast, fulfilling a condition of British Columbia's 1871 entry into the Canadian Confederation. The City of Vancouver, incorporated in 1886, was designated the western terminus of the line. The CPR became the first transcontinental railway company in North America in 1889 after it International Railway of Maine opened, connecting CPR to the Atlantic coast.

The construction of a transcontinental railroad had the effect of establishing a Canadian claim to the remaining parts of British North America not yet constituted as provinces and territories of Canada, acting as a bulwark against potential incursions by the United States.

Subsequently, two other transcontinental lines were built in Canada: the Canadian Northern Railway (CNoR) opened another line to the Pacific in 1912, and the combined Grand Trunk Pacific Railway (GTPR) /National Transcontinental Railway (NTR) system opened in 1917 following the completion of the Quebec Bridge, although its line to the Pacific opened in 1914. The CNoR, GTPR, and NTR were nationalized to form the Canadian National Railway, which currently is now Canada's largest transcontinental railway, with lines running all the way from the Pacific Coast to the Atlantic Coast.

4.1.1.3 **Central America (Inter-oceanic lines)**

4.1.1.3.1 **Panama**

The first railroad to directly connect the two oceans (although not by crossing a wide "continental" land mass) was the Panama Rail Road. Opened in 1855, this 48-mile (77 km) line was designated instead as an "inter-oceanic" railroad crossing Central America at its narrowest point, the Isthmus of Panama, when that area was still part of the northern province of Colombia from which it would split off to become the independent nation of Panama in 1903. By spanning the isthmus, the line thus became the first railroad to completely cross any part of the Americas and physically connect ports on the Atlantic and Pacific Oceans. Given the tropical rainforest environment, the terrain, and diseases such as malaria and cholera, its completion was a considerable engineering challenge. The construction took five years after ground was first broken for the line in May, 1850, cost eight million dollars, and required more than seven thousand workers drawn from "every quarter of the globe."

This railway was built to satisfy the need for a shorter and more secure path between the United States' East and West Coasts, a need triggered mainly by the California Gold Rush. Over the years it played a key role in the construction and the subsequent operation of the Panama Canal, due to its proximity with the waterway. Currently, the railway operates under the private administration of the Panama Canal Railroad Company, and its upgraded capacity complements the cargo traffic through the Panama Canal.

4.1.1.3.2 **Guatemala**

A second Central American inter-oceanic railroad began operation in 1908 as a connection between Puerto San José and Puerto Barrios in Guatemala, but ceased passenger service to Puerto San José in 1989.

4.1.1.3.3 **Costa Rica**

A third Central American inter-oceanic railroad began operation in 1910 as a connection between Puntarenas and Limón which was 1,067 mm (3 ft 6 in) gauge.

4.1.1.3.4 **Mexico - Panama**

- FERISTSA - a proposed 1,435 mm (4 ft 8 $^1/_2$ in) north-south line.

4.1.1.4 **South America**

There is activity to revive the connection between Valparaíso and Santiago in Chile and Mendoza, Argentina, through the *Transandino* project. Mendoza has an active connection to Buenos Aires. The old Transandino began in 1910 and ceased passenger service in 1978 and freight 4 years later... Technically a complete transcontinental link exists from Arica, Chile, to La Paz, Bolivia, to Buenos Aires, but this trans-Andean crossing is for freight only.

Another longer Transcontinental freight-only railroad linking Lima, Peru, to Rio de Janeiro, Brazil is under development.

4.1.1.5 **Eurasia**

- The first Eurasian transcontinental railroad was the Trans-Siberian railway (with connecting lines in Europe), completed in 1905 which connects Moscow with Vladivostok on the Pacific Coast. There are two connections from this line to China. It is the world's longest rail line at 9,289 km (5,772 mi) long. This line connects the European railroad system with China, Mongolia and Korea. Since the former Soviet countries and Mongolia use a wider gauge, a break of gauge is necessary either at the eastern frontiers of Poland, Slovakia, Hungary and Romania or the Chinese border. In spite of this there are through services of passenger trains between Moscow and Beijing or through coaches from Berlin to Novosibirsk. Almost every major town along the Trans-Siberian railway has its own return service to Moscow.

- A second rail line connects Istanbul in Turkey with China via Iran, Turkmenistan, Uzbekistan and Kazakhstan. This route imposes a break of gauge at the Iranian border with Turkmenistan and at the Chinese border. En route there is a train ferry in eastern Turkey across Lake Van. The European and Asian parts of Istanbul are linked by a train ferry, and an undersea tunnel is under construction. There is no through service of passenger trains on the entire line. A uniform gauge connection was proposed in 2006, commencing with new construction in Kazakhstan. A decision to make the internal railways of Afghanistan 1,435 mm (4 ft 8 ½ in) gauge potentially opens up a new standard gauge route to China, since China abuts this country.

4.1.1.6 Asia

- The Trans-Asian Railway is a project to link Singapore to Istanbul and is to a large degree completion with missing pieces primarily between Iran and Pakistan (under construction in 2005), and in Myanmar, aside from political issues. The project was also linked corridors to China, the central Asian states, and Russia. This transcontinental line unfortunately uses a number of different gauges, 1,435 mm (4 ft 8 ½ in), 1,676 mm (5 ft 6 in), 1,520 mm (4 ft 11 27⁄32 in) and 1,000 mm (3 ft 3 3⁄8 in), though this problem may be lessened with the use of variable gauge axle systems such as the SUW 2000.
    - The Zahedan connection opened in August 2008.
- The TransKazakhstanTrunk Railways project by Kazakhstan TemirZholy will connect China and Europe at a gauge of 1,435 mm (4 ft 8 ½ in). Construction is set to start in 2006. Initially the line will go to western Kazakhstan, south through Turkmenistan to Iran, then to Turkey and Europe. A shorter to-be-constructed 1,435 mm (4 ft 8 ½ in) link from Kazakhstan is considered going through Russia and either Belarus or Ukraine.
- The Baghdad Railway connects Istanbul to Baghdad and finally Basra, a seaport on the Persian Gulf. When its construction started in the 1880s it was in those times a Transcontinental Railroad.

4.1.1.7 Australia

4.1.1.7.1 East-West

- The first Trans-Australian Railway was completed in 1917, between Port Augusta and Kalgoorlie, and crosses the Nullarbor Plain. This line completed the link between the mainland state capitals of Brisbane then Sydney via Melbourne and Adelaide to the western state capital of Perth. This route suffered from a number of breaks-of-gauge, using 1,435 mm (4 ft 8 ½ in) twice, 1,600 mm (5 ft 3 in) once, and 1,067 mm (3 ft 6 in) thrice, with five breaks-of-gauge in all.

The Trans-Australian Railway was the first route operated by the Federal Government.

In the 1940s, 1970s, and 2000s steps were taken to rationalize the gauge chaos and connect the mainland capital cities mentioned above with a streamlined 1,435 mm (4 ft 8 ½ in) uniform gauge system. Since 1970, when the direct line across the country was all completed as standard gauge, the passenger train on the Sydney to Perth line has been called the Indian Pacific.

The proposed Iron Boomerang would connect iron in the Pilbara with coal in Queensland, so achieving loaded operations in both directions.

4.1.1.7.2 North-South

- An 820-mile (1,320 km) long land grant railway from Charleville to Point Parker on the Gulf of Carpentaria, with branches, was proposed in the 1880s.
- The first north-south trans-Australia railway opened in January 2004 and links Darwin to Adelaide with the Ghan passenger train. The Adelaide-Darwin railway is standard or 1,435 mm (4 ft 8 $\frac{1}{2}$ in) gauge, though the original line to Alice Springs (never fully completed line) was 1,067 mm (3 ft 6 in) gauge.
- In 2006, proposals for new lines in Queensland that would carry both intrastate coal traffic and interstate freight traffic would see standard gauge penetrate the state in considerable stretches for the first time. (ARHS Digest September 2006). The standard gauge Inland Railway would ultimately extend from Melbourne to Cairns.
- Starting in 1867, Queensland built several railways going inland from several ports in a westerly direction. From the 1920s, steps were taken to connect these lines by the North-South North Coast line from Brisbane to Cairns.

4.1.1.8 **Africa**

4.1.1.8.1 **East-West**

- There are several ways to cross Africatranscontinentally by connecting west-eastern railroads. One is the Benguela railway that was completed in 1929. It starts in Lobito, Angola and connects through Katanga to the Zambia railway system. From Zambia several ports are accessible to the Indian ocean: Dar Es Salaam in Tanzania through the TAZARA, and, through Zimbabwe, Beira and Maputo in Mozambique. The Angolan Civil War has made the Benguela line largely inoperative, but efforts are being taken to restore it. Another west-east corridor leads from the Atlantic habours in Namibia, either Walvis Bay or Luderitz to the South African rail system that, in turn, links to ports on the Indian Ocean (i.e. Durban, Maputo).
- A 1015 km gap in the east-west line between Kinshasa and Ilebo filled by riverboats could be plugged with a new railway.
- There are two proposals for a line from the Red Sea to the Gulf of Guinea, including TransAfricaRail.
- In 2010 a proposal surfaced linking Dakar to Port Sudan. Thirteen countries are on the main route, while another six would be served by branches.

4.1.1.8.2 **North-South**

- A North-South transcontinental railroad had been proposed by Cecil Rhodes: the Cape-Cairo railway. This system was seen as the backbone for the African possessions of the British Empire, and was not completed. During its development, a competing French colonial project for a *Trany* line from Algiers or Dakar to Abidjan was abandoned after the Fashoda incident. This line would have four gauge islands in three gauges.
- An extension of Namibian Railways is being built in 2006 with the possible connection to Angolan Railways.
- Libya has proposed a Trans-Saharan Railway connects possibly to Nigeria which would connect with the proposed AfricaRail network.

4.1.1.8.3 **African Union of Railways**

- The African Union of Railways has plans to connect the various railways of Africa including the Dakar-Port Sudan Railway.

4.1.2 Sea Routes

Mariners have made use of the ice-free waters on the periphery of the Arctic Ocean for hundreds of years, and the flow of marine traffic has risen throughout the 20^{th} century. Studies now suggest that, due to retreating sea ice cover, the ocean could be ice-free for a short period as early as summer 2015. Regardless of when this may happen, maritime activity in the Arctic is poised to reach global prominence in the not-distant future.

Approximately 6,000 individual vessels currently operate in Arctic waters. This includes tankers, bulk carriers, offshore supply vessels, passenger ships, tug/barge combinations, fishing vessels (about 1600), ferries, research vessels, and government and commercial icebreakers. The three primary demands for shipping services are: moving natural resources out of the region, supplying goods to communities, and tourism. The highest concentrations of marine activity occur along the coastal northwest Russia, and in the ice-free waters off Norway, Greenland, Iceland, and Alaska. Ship-based scientific exploration and research is on the rise, as is cruise ship traffic, particularly around Greenland.

Maritime transport utilizes some 17 ports and harbors. Only a few of these handle high volumes of raw materials for shipping to production and consumption centers. A number of smaller ports support passenger services and fishing. Major ports and harbors include:

- **Russia -** Murmansk, Arkhangelsk, Labytnangi/Salekhard, Dudinka, Igarka, Dikson, Tiksi, and Pevek
- **Canada** - Churchill (Manitoba), Inuvik and Tuktoyaktuk (Northwest Territories), Nanisivik (Nunavut)
- **Norway -** Longyearbyen, Kirkenes, and Vardø
- **United States** (Alaska) – Barrow and Valdez

Two sea routes are becoming very important. The first is the Northern Sea Route, a water course north of Eurasia that stretches from Novaya Zemlya (Russia) in the west to the Bering Strait in the east. Since 1978–79, Russian government ice-breaking ships have maintained year-round navigation of much of the route, which opened to international marine traffic in 1991. The second emerging route is the Northwest Passage, which traverses the northern coastal waters of North America, winding through the Canadian Arctic Archipelago to the Bering Strait. A limited number of ships have navigated the entire passage since 2000.

In late August 2008, for the first time in 125,000 years, both the Northwest Passage and Northern Sea Route were open and navigable simultaneously. The landmark event heightened the plausibility of “shortcut” routes that would greatly reduce the distance and travel time, during summer, for shipping goods between Pacific and Atlantic coasts in Europe and North America. Nonetheless, the winter sea ice cover is projected to remain indefinitely, and changing ice conditions will continue to pose considerable challenges for marine operations.

The Northern Sea Route is already fully open up to eight weeks a year, with ships transporting about a 1.5 million tons of goods. As this route runs through fairly open waters and summertime ice conditions can be relatively stable, the chances are good that it will see even heavier traffic in the coming years. In contrast, the Northwest Passage snakes through a labyrinth of Canadian islands, where shifting ice conditions can imperil ship traffic. Major investments in escort vessels and staging ports will be required to make the route a viable thoroughfare, which will likely take decades.

Another possible, even shorter trans-Arctic sea route has been proposed: a more or less straight course that would utilize icebreakers to plow through frozen sections of the Arctic Ocean, where ice thickness averages about 2.5 meters. Presumably, this would require a fleet of icebreakers. Currently only a small number of such ships are in service. Russia operates seven civilian nuclear-powered icebreakers and plans to build another by 2015.

While climate change appears to be driving the polar North toward expanded maritime activity, the overall shortage of major ports and other critical infrastructure will be significant limitations. Detailed navigational maps, meteorological and oceanographic data, and radio and satellite communications are generally lacking (except for areas along coastal Norway and northwest Russia). These deficits, combined with the remote and harsh quality of the environment make emergency response to marine accidents much more difficult than in many other regions. As the Arctic Council's 2009 Arctic Marine Shipping Assessment notes, the expansion of infrastructure must include enhancing safety at sea and protecting the ocean environment. Meeting these considerable challenges will require close cooperation between Arctic states, industry, and other public and private groups.

4.1.3 Air transport

Air transportation was slow to take off after the Wright Brothers breakthrough at Kitty Hawk in 1903. More than ten years passed before first faltering efforts to launch scheduled passenger services. On January 1, 1914, the world's first scheduled flight with a paying passenger hopped across the bay separating Tampa and St. Petersburg, Florida for a fare that eventually stabilized at $10 per person, round-trip (about $200 in 2006 dollars). By comparison, Low-Cost Carrier (LCC) Southwest Airlines could carry a passenger from Tampa to Seattle and back, more than **a hundred times farther** for only slightly more than $200 in 2007. World War I, which began just months after that first flight from Tampa, provided the first real spur to the development of commercial aviation as air power began to be used and better aircraft were quickly designed. The war left a legacy of thousands of unemployed pilots and surplus aircraft along with an appreciation for the future significance of this new technology. However, air transport still suffered from limitations in terms of capacity and range. 1919 marked the first commercial international air transport service between England and France. It was also the same year that with the Paris Convention that each country controlled the airspace over its territory. Governments played a crucial role in the next phase of aviation history. In Europe, governments established new passenger airlines while on the other side of the Atlantic, the American government heavily **subsidized airmail**. Airmail was one of the earliest avenues via which air transportation became commercially relevant because it helped to accelerate the velocity of the cash supply and helped to better tie together far-flung enterprises, facilitating the emergence of continental and intercontinental enterprises. US airmail also subsidized the emergence of the first major US passenger airlines. By the eve of World War II, air travel was quite literally taking off, borne aloft by important advances in technology. Particularly important was the Douglas DC-3, the first airliner that could fly profitably without government subsidies (air mail routes). The 21-seat DC-3 was a long-range aircraft for its time, able to fly across the US stopping just three times. By 1941, 80% of all commercial aircraft in the US were DC-3s. The DC-3 was a landplane; but on longer-haul, intercontinental routes, flying boats remained common through World War II. Flying boats, like the double-deck Boeing 314, were the largest commercial aircraft until the building of the 747. They could fly very long distances but their slow speeds undercut their profitability. And the market for long-haul travel was very small, partly because of the extraordinarily high cost. Many of the long-haul air services were to colonies and dependencies. Only the elite or government officials were able to afford air travel. War again encouraged the rapid growth of air transportation. Indeed, it was only after World War II that air transportation became the dominant mode of long-haul passenger travel in developed countries. In 1956, more people traveled on intercity routes by air than by Pullman car (sleeper) and coach class trains combined in the US. In 1958, airlines carried more passengers than ocean liners across the Atlantic for the first time. Even more momentous, in October 1958, the Boeing 707 took its maiden commercial flight. The 707 was not the first jetliner, but it was the first successful one. The 707 and other early jets, especially the Douglas DC-8, doubled the speed of air transportation and radically increased the productivity of airlines which enabled fares to fall. Just a few years after the 707's debut, jet service had been extended to most major world markets. Jet transportation facilitated the extension of the linkages between people and places, which is supported by ample evidence. A classic example concerns American major league baseball. Through the mid-1950s, all major league teams were located in the Manufacturing Belt, situated no more than an overnight rail journey apart from one another to permit closely packed schedules. The speed and ultimately lower cost of air transportation freed teams to move into the untapped markets of the Sunbelt so that by the mid-1960s, half a dozen teams were strung out across the South and West. In the years since the beginning of the Jet Age, commercial aircraft have advanced markedly in capacity and range. Just 12 years after the debut of the 707, the 747 made its maiden flight. Not coincidentally, it too premiered on a transatlantic route from New York City. The entry of dozens of 747s into the market around the same time that the Arab Oil Embargo triggered a worldwide recession led to a torrent of red ink for early Jumbo enthusiasts like Pan Am; but the long term effect was to **push real airfares ever downward**, thereby democratizing aviation beyond the so-called "Jet Set". The 747, particularly the longer-range 747-400 version introduced in the late 1980s, has been nicknamed the "Pacific Airliner" because of its singular significance in drawing Asia closer to the rest of the world and because Asia-Pacific airlines have been major 747 customers. Since their introduction in the late 1950s, commercial jets have not improved in terms of speed. The fastest airliners in regular use today are about as fast as the 707. The Anglo-French Concorde which cruised at twice the speed of sound was hamstrung by very poor economics – it weighed half as much as a first-generation 747 but could carry only a quarter as many passengers and had a range more than 3,000 kilometers shorter. Moreover, the Concorde was an early target of the nascent environmental movement, and restrictions on overland supersonic flights severely limited the market for the airliner. The only carriers to regularly operate it were British Airways and Air France, and although many cities had Concorde services in the first halcyon years of its early use, by the time the supersonic transport (SST) was finally grounded in 2003, only London, Paris, New York, and Washington had scheduled year-round services. Three major categories of passenger jet planes may be recognized:

- **Short range aircraft**. Bombardier's CRJ series and Embraer's ERJs are examples of planes with relatively small capacities (30-100 passengers) that travel over relatively short distances. They are usually referred to as regional jets that serve smaller markets and feed hub airports. They also provide high frequency point to point services between large city pairs.
- **Medium range aircraft**. The Airbus A320, with a range of 3,700 km, and its Boeing equivalent, the B-737, is designed to service destinations within a continent. From New York, most of North America can be reached. This range can be applied to the European continent, South America, East Asia and Africa. This type of aircraft is also used for high demand regional services where low cost air carriers compete.
- **Long range aircraft**. There are a variety of aircraft capable of crossing the oceans and linking together the continents. Early variants such as the B-707 have evolved into planes offering high capacity, such as the B-747 series, or long range abilities, such as B-777 series or the A350 series which have ranges of up to 17,400 km.

2. Economic and Spatial Impacts- It is through **increasingly long-haul nonstop services** among an ever wider set of city-pairs rather than through increased aircraft speeds that air transportation continues to

"shrink the world". After World War II aircraft were just beginning to be capable of crossing the Atlantic without stopping at intermediate places such as Newfoundland. In the mid-1950s, the Israeli carrier El Al advertised its transatlantic services with the slogan "No Goose, No Gander" to cleverly let travelers know that its turboprop services had to stop at neither Goose Bay nor Gander in Newfoundland to refuel. Today, commercial aircraft are now capable of making trips of up to 18 hours in duration. Such ultra-long-range flights servicing the world's metropolises are both a response and a driver for globalization. The same capacity of air transportation to dramatically lower the cost (friction) of distance has, of course, been instrumental in fostering economic globalization, albeit in a highly uneven fashion. Manufacturers, especially those producing high-value microelectronics, are heavily reliant upon air transport to tie together spatially disaggregated operations. Intel, the world's foremost computer chip manufacturer is an example of a firm that relies heavily on air transportation, both passenger and cargo, to tie together its global production network. The firm's Philippine operations, for instance, receive their main inputs and export their output almost exclusively by air. Relatively inexpensive air transport has also been crucial to the **growth of tourism**. It is no coincidence, for instance, that the five major Disney theme parks are all located near one of the world's thirty busiest airports: Disneyworld near Orlando International Airport, Disneyland near Los Angeles International Airport, Euro Disney near Paris-Charles de Gaulle, Tokyo Disneyland near Tokyo-Haneda, and the newest park in Hong Kong which shares Lantau island with the most expensive airport in history. Microelectronics and tourists comprise only two of the many kinds of airborne traffic. Since the dawn of the Jet Age, air transport has ascended to astonishing heights. It is overwhelmingly dominant in transcontinental and intercontinental travel and is becoming more competitive for shorter and shorter trips. In the US, for instance, air travel is the most important mode for trips more than about 1,100 kilometers in one-way length. In developing countries, too, LCCs are proliferating, which is bring air fares down and propelling air traffic higher. Therefore, the world's busiest air routes are not long haul flights, but short range flights between cities less than 1,000 km apart. Through the Jet Age, both passenger and cargo traffic have grown rapidly. Both types of traffic have outpaced the growth of the wider global economy. By 2003, approximately 900,000 people were airborne on scheduled flights somewhere in the world at any one time; and worldwide, 1.6 billion passengers traveled by air transport in the centenary of the Wright Brothers' first flight, representing the equivalent of 25% of the global population. At 2010, this figure reached 2.4 billion passengers, underlining the enduring growth of air travel. Yet the propensity to fly is highly uneven. Alone, North America and Europe accounted for 70.4% of all passenger movements in 2000, but this share is declining. At any given time, there are more than 5,000 planes in the air over North America. Air transportation's share of world trade in goods is only 2% measured by weight but more than 40% by value. For the international operations, freight can account for 45% of the revenue of a regular airline. Typically, air cargo relates to time sensitive, valuable or perishable freight carried over long distances. This is particularly suitable in supporting "just-in-time" production and distribution strategies with low inventory levels. Air cargo has also a niche market for emergency situations where the fast delivery of supplies (e.g. medical, food) prevails over cost issues. The air freight market is serviced by five types of operations:

- **Dedicated cargo operators** maintaining a fleet or cargo-only aircrafts and offering regular scheduled services between the airports they service. They also offer charter operations to cater to specific needs.
- **Combination services** where an airline company will maintain a fleet of both specialized and passenger aircrafts able to carry freight in their bellyhold. Most of the cargo operations involve long haul services.
- **Passenger operators** that will offer the freight capacity in the bellyhold of their aircrafts. For these operators, freight services are rather secondary and represent a source of additional income. It still remains an important market as about 50% of all the air cargo is carried in the bellyhold of regular passenger aircrafts. However, low cost airlines usually do not offer air cargo services.

- **Air freight integrates** commonly operating hub and spoke freight services that reconcile short and long haul flights. They offer comprehensive services that are usually door-to-door and can support the logistics requirements of their customers.
- **Specialized operators** fulfilling niche services that cater to specific cargo requirements (e.g. heavy loads) that do not fit the capabilities of standard cargo aircrafts.

Efficient and affordable air freight have contributed to changes in diet by making available new products or products in seasons during which they would not be available, to changes in retailing and correspondingly to changes in manufacturing. Examples abound, such as fresh produces growth in the southern hemisphere available in the northern hemisphere during winter, or merchandises purchased online and shipped promptly by air transport or a computer manufacturer depending on the global shipment of various components in the manufacturing and assembly processes. The increased importance of **time-based competition** ensures that air cargo augurs well for the future growth of air transportation. 3. The Geography of Airline Networks Theoretically, air transport enjoys **greater freedom of route choice** than most other modes. Yet while it is true that the mode is less restricted than land transport to specific rights of way, it is nevertheless much more constrained than what might be supposed. Early in the history of aviation, physical obstacles such as the Rocky Mountains and the great gap of the North Atlantic limited the articulation of air transport networks. While those limitations have fallen, physical geography still affects the geography of intercity air transportation. Aircraft seek, for instance, to exploit (or avoid) upper atmospheric winds, in particular the **jet stream**, to enhance speed and reduce fuel consumption. Volcanic eruptions may also impede air travel by releasing ash in the atmosphere, which can damage and even shut down turbofan engines. Such occurrences are however rare and punctual, with the exception of April 2010 when a volcanic eruption in Iceland forced the closing down of airports in most of Europe as well as several North Atlantic routes. This represented the largest natural disruption of air travel in history. Yet the limitations that structure air transportation are **mainly human creations**. First, in the interest of air safety, air traffic is channeled along specific corridors so that only a relatively small portion of the sky is in use. Jetway 554, for example, which passes from high over the Michigan-Indiana state line towards Jamestown, New York via Southern Ontario, accommodates flights from many different cities in the West and Midwest bound for the Northeast, with nonstop city-pairs such as San Diego-Boston, Chicago-Albany, Phoenix-Providence, and Los Angeles-Hartford. China is facing significant air capacity constraints not because its airports are congested, but mostly because a large segment of the airspace is regulated by the military. **Strategic and political factors** have also influenced route choice. For example, the flights of South African Airways were not allowed to over-fly many African nations during the apartheid period, and Cubana Airlines has been routinely prohibited from over-flying in the US. Even more significant was the opening up of Siberian airspace to Western airlines after the Cold War. The new freedom permitted more direct routes not only between cities like London and Tokyo or New York and Hong Kong but also between transpacific city pairs like Vancouver-Beijing. Few large areas of airspace forbidden to carriers on political grounds remain. However, the intervention of the state in airline networks remains pervasive. From its infancy, air transport was then seen as a public service and as an industry that should be regulated and protected. In many parts of the world, government intervention in the industry took the form of state-owned airlines. As recently as the early 1970s, Air Canada, Air France, British Airways, Japan Airlines, Qantas, and most other flag carriers throughout the world were fully state-owned. In the US, the government did not own any airlines but it did strongly affect the industry's development via regulation of fares, in-flight service, routes, and mergers. Beginning in the 1970s, the relationship between the airline industry and the state changed, although the timing of liberalization (a term which refers to both deregulation and privatization) and its extent has varied among the world's main markets. Across the globe, dozens of airlines have been at least partially privatized, and many airline markets have been deregulated. In the United States, the Air Deregulation Act of 1978 opened the industry to competition. The results, seen from the vantage point of more than 25 years later, have been dramatic. Once hallowed names, like TWA, Pan Am, and Braniff sank into bankruptcy (though Pan Am has been reborn as a much smaller carrier along the Atlantic coast) and many new players emerged. Most lasted only a short time, but some have had a profound, enduring effect on the industry and air transportation more generally. 4. Deregulation and its Consequences Geographically, a key outcome of airline deregulation has been the emergence of hub-and-spoke networks centered on a major airport where a single carrier is often dominant. Such networks existed before deregulation to some degree, but the Civil Aeronautics Board hampered the expansion of airlines and the rationalization of networks. United Airlines, for instance, was allowed to add only one city to its network between 1961 and 1978. Hub-and-spoke systems rely on the usage of an intermediate airport hub. They can either connect a domestic (or regional) air system if the market is large enough (e.g. United States, China, European Union) or international systems through longitudinal (e.g. Dubai, Reykjavik) or latitudinal (Panama City) intermediacy. An important aspect of an intermediate hub concerns maintaining schedule integrity since the majority of passengers are using connecting flights. Airports that are prone to delays due to congestion are not effective hubs since they compromise the schedule integrity. After deregulation, most of the surviving major carriers tended to construct nationwide hub-and-spoke networks with several hubs to facilitate travel between different regions of the country. The traffic feed through hubs like Atlanta enables Delta and other carriers to offer higher frequency service at higher load factors which in turn lowers the per passenger-kilometer cost. The advantages of large airlines were further deepened when nationwide hub-and-spoke networks were coupled to computer reservations systems and frequent flyer programs. Yet by the late 1990s, large carriers like Delta were on the run. Low cost carriers, especially Southwest Airlines in North American and Ryanair in Europe, cut into the market share of the "legacy" carriers. LCCs are distinguished by several common features:

- **Fleet simplicity**. Legacy carriers operate diverse fleets because they serve many kinds of routes, from long hauls to feeders. LCCs emphasize on relatively short-haul routes. The minimal number of aircraft types (Southwest and Ryanair only fly 737s, though several different models) lowers costs.
- **Fast turnaround times**. LCCs operate their networks in ways that keep their aircraft in the air earning cash for a higher number of hours on average compared to the legacy carriers. Minimal inflight service, for instance, reduces the time needed to clean and cater flights.
- **Rapid growth**. This is not just a product of the LCCs' success but an element in it. Fast growth enables the LCCs to continue to add aircraft and staff at a steady pace which keeps the average fleet age and average years of employee service low – both of which help to keep operations costs low.
- **Emphasis on secondary airports**. Secondary airports, such as Houston-Hobby instead of George Bush Houston Intercontinental or Charleroi instead of Brussels National, typically have lower landing and parking fees for airlines as well as a more entrepreneurial approach to recruiting new airline service. However, LCCs also directly challenge established carriers in major hubs.
- **Reduced importance of hubs**. Most LCCs do have hobbies, but for some carriers hubs are substantially less important than they are for legacy carriers. Southwest Airlines, for instance, distributes air traffic more evenly among a ten or so top "focus cities" in its network than is true of any traditional hub-and-spoke airline.
- **Aggressive use of the Internet**. Internet booking partially neutralized the one-time advantage that legacy carriers enjoyed through their proprietary computer reservations systems. The Internet is an additional way of reducing costs.

Although Southwest Airlines are commonly regarded as the pioneer LCC and is the only LCC to rank among the world's 20 largest airlines, the phenomenon has now taken off in Europe and to a lesser extent in other parts of the world. In general, the propensity to travel is highly correlated with incomes, but the LCCs are important in widening the air transportation market beyond the relatively small affluent population in countries like Indonesia. Southwest Airlines is exceptional in that its network is purely domestic (International flights are operationally more complex and would erode the carrier's enviable turnaround time.) Most large and medium-sized airlines have at least some international routes. Nevertheless, about 90% of the air traffic generated by countries such as the United States, Canada, Russia, Japan, Brazil and Australia are domestic. The United States alone generates 70% of the global domestic air traffic. Under threat by LCCs in shorter-haul markets, legacy carriers are becoming more dependent on long-haul international markets. International markets, too, have been opened up by deregulation, though not to the same degree as the US domestic market. The Chicago Convention of 1944 established the basic geopolitical guidelines of international air operations, which became known as the air freedom rights. First and second freedom rights almost automatically exchange among countries. The US, which emerged from World War II with by far the strongest airline industry in the world, had wanted third and fourth freedom rights to be freely exchanged as well. Instead, these and the other rights have been the subject of hundreds of carefully negotiated bilateral air services agreements (ASAs). In an ASA, each side can specify which airlines can serve which cities with what size equipment and at what frequencies. ASAs often include provisions that also regulate fares and the sharing of revenue among the airlines serving a particular international route. Yet even in international markets, the extent and degree of **state intervention have diminished**. An important trend in the past decade has been the proliferation of Open Skies agreements. Open Skies agreements remove most restrictions on the number of carriers and the routes that they may fly between two countries. This is irrespective of the size of the size of the respective air markets as long as national carriers are granted equal rights. By the end of 2006, the US, for instance, had such agreements with nearly 80 countries. Open Skies agreements can be viewed as a roundabout way for the US to gain what it could not get at the 1944 Chicago Conference – relatively unfettered access for American carriers to foreign markets. Indeed, the US has pursued a beachhead strategy playing one country in a region against another, putting pressure on Japan to liberalize its markets for instance by inaugurating Open Skies agreements with Singapore, Taiwan, South Korea and other Asian economies. Potentially the most important Open Skies agreement would be between the US and European Union, which began in 1992 with an Open Skies agreement with the Netherlands, an important hub in the European air network. This also incites the setting of alliance agreements between carriers. Moves in that direction have been stymied by the US unwillingness to relax restrictions on foreign ownership of American carriers, among other concerns. Nevertheless, many more airlines now operate internationally than before the liberalization of the airline industry began in the 1970s. The proliferation of international carriers has fostered the fragmentation of intercontinental and transcontinental markets. As a result, on intercontinental and transcontinental routes, the former dominance of the 747 has been challenged by longer-range, Widebody twinjet (two-engine jetliners) like the Boeing 767, Boeing 777, and Airbus A330. The triumph of Widebody twinjets is most evident in the transatlantic market. The transpacific market is more concentrated among a smaller number of gateway cities, and the 747 is still dominant; but there is a clear trend towards fragmentation and displacement of the 747 by smaller aircraft, including ultra-long-range ones like the A340-500. An important aspect of international airline networks is the recent formation of alliances. Alliances are voluntary agreements to enhance the competitive positions of the partners, particularly where the persistence of restrictive bilateral ASAs makes it difficult for an airline to expand on its own. Members benefit from greater scale economies, a lowering of transaction costs, and a sharing of risks, while remaining commercially independent. The first major alliance was established in 1989 between KLM and Northwest Airlines. Today, the largest alliance is the Star Alliance, which was initiated in 1993 by Lufthansa and United Airlines. In 1996 British Airlines and American Airlines formed the OneWorld alliance. Members of airline alliances cooperate on scheduling, frequent flyer programs, and equipment maintenance, and schedule integration. Most importantly, they permit carriers to tap markets that would otherwise be beyond their reach. Indeed, each of the major alliances encompasses almost every significant market across the globe, although each is dominated by US and European carriers. A final important aspect of airline networks is the emergence of separate air cargo services. Traditionally, cargo was carried in the bellyhold of passenger airplanes, and provided supplementary income for airline companies. However, since passengers always had the priority when a plane was overloaded, such air freight services **tended to be unreliable**. Moreover, passenger aircraft operate on routes that make sense for passengers, but may not attract much cargo. Today, about half of all air cargo is carried in dedicated freighters, the aircraft in which goods are both carried on the main deck and in the bellyhold. FedEx and UPS operate the largest freighter fleets in the world, operating 338 and 243 freighters respectively (by comparison, the largest passenger airline fleet is that of American Airlines with nearly 700 aircraft). Each deploys its aircraft worldwide. Yet many freighters have been flown from so-called combination carriers like Northwest that carry both passengers and cargo. Northwest deploys its freighters primarily on transpacific routes were too little bellyhold capacity is available to accommodate the burgeoning trade between the US and Asia. Interestingly, one of the primary freighter hubs is Anchorage, a city which passenger aircraft on transpacific and transpolar routes (between Europe and Asia) regularly overfly now; but because freighters have shorter ranges than passenger aircraft and because freight is less sensitive to intermediate refueling stops than passengers, many freighters refuel in Alaska in order to maximize their payload. Still, cargo operations are ripe with inefficiencies. About 70% of the transit time for a payload carried by air is spent on the ground, mostly in congested major airport terminals. This tends to mitigate the major speed advantage air freight is known for. 5. The Future of Flight Although the past century witnessed the dramatic growth of air transportation, important challenges cloud its future. First, the airline industry may **not be financially healthy enough** to pay for commercial advances that have benefited to the continuing growth of air transportation in the past. The development costs of new jetliners, even after adjusting for inflation, are unprecedented, partly because the latest generation of aircraft incorporates so many interfacing systems (e.g. in-seat inflight entertainment consoles). Meanwhile, the rise of the LCCs has put great pressure on the bottom lines at legacy carriers, and overall the airline industry has not been especially profitable. The financial woes of the industry have implications for the future of air transportation for it is the great carriers that have provided the launch orders for new airliners in the past. Pan Am, for instance, launched the 707 and 747; United launched the 767 and 777; and Air France and Lufthansa provide the launch orders for most of Airbus' airliners. By contrast, the LCCs' focus on a handful of smaller, relatively short-haul aircraft limits their capacity to serve as catalysts for technological breakthroughs in aviation. It should be quickly noted, however, that not all legacy carriers are struggling. Singapore Airlines, in particular, has emerged as one of the industry's most consistently profitable legacy carriers and one of the aircraft industry's most important customers. SIA is a launch customer for the 555-seat Airbus A380 which ended the 747's long reign as the largest regularly used commercial aircraft when the "Superjumbo" finally took paying passengers in 2007. Asian carriers more generally are key players in the airline and aircraft industries today. Boeing has bet that Asian markets will be fragmented like those over the Pacific and has tailored its newest offering, the 787 Dreamliner, for that purpose. Interestingly, both the A380 and 787 are very long-range aircraft. Both Boeing and Airbus promise that their newest jetliners will offer unparalleled fuel efficiency. That is important because a second basic threat to the future of the airline industry is the price and availability of fuel. In 2006, fuel accounted for about 30% of the operating costs of US airlines, up sharply from a few years earlier. For air transportation, finding a substitute for oil-based fuels is much more difficult than in ground transportation because the economic viability of flight depends on the use of a concentrated form of explosive energy. There is no easy substitute for fossil fuels in this regard. Still, the fuel efficiency of air transport has substantially improved in recent decades, as high as 70% between 1960 and 2000, and possible future reductions are expected to take place at a rate of 1 to 2% per year. A third threat is terrorism and security. The rise of the airline industry was facilitated in part by the steady advance in the safety and predictability of air travel from the early post-WW I days of "Flying Coffins". Terrorism directed against civil aviation threatens the confidence of ordinary travelers in addition to impose additional security constraints taxing passengers in terms of delays. The September 11 attacks caused a two-year dip in traffic levels. The attacks of that day were unprecedented not only in their scale but also in their geography. Although American carriers had been targeted before, no major terrorism incident against the airline industry had occurred in the US previously. Instead, earlier attacks against aircraft and airports and airlines had been concentrated in Europe and the Middle East. Last, with the growth of air traffic, airports are facing capacity pressures and congestion which in some cases has resulted in changes in the scheduling of flights. The will to fly seems irrepressible, and aviation is now inextricably entwined in the fabric of 21st century everyday life across much of the world.

4.2 International Trade: Patterns & Trend

International trade is the exchange of capital, goods, and services across international borders or territories. In most countries, such trade represents a significant share of gross domestic product (GDP). While international trade has been present throughout much of history, its economic, social, and political importance has been on the rise in recent centuries.

Industrialization, advanced in technology, transportation, globalization, multinational corporations, and outsourcing are all having a major impact on the international trade system. Rising international trade is crucial to the continuance of globalization. Without international trade, nations would be limited to the goods and services produced within their own borders.

International trade is, in principle, not different from domestic trade as the motivation and the behavior of parties involved in a trade do not change fundamentally regardless of whether trade is across a border or not. The main difference is that international trade is typically more costly than domestic trade. The reason is that a border typically imposes additional costs such as tariffs, time costs due to border delays and costs associated with country differences such as language, the legal system or culture.

Another difference between domestic and international trade is that factors of production such as capital and labor are typically more mobile within a country than across countries. Thus international trade is mostly restricted to trade in goods and services, and only to a lesser extent to trade in capital, labor or other factors of production. Trade in goods and services can serve as a substitute for trade in factors of production.

Instead of importing a factor of production, a country can import goods that make intensive use of that factor of production and thus embody it. An example is the import of labor-intensive goods by the United States from China. Instead of importing Chinese labor, the United States imports goods that were produced with Chinese labor. One report in 2010 suggested that international trade was increased when a country hosted a network of immigrants, but the trade effect was weakened when the immigrants became assimilated into their new country.

International trade is also a branch of economics, which, together with international finance, forms the larger branch of international economics. Trading is a value added function of the economic process of a product finding its market, where specific risks are to be borne by the trader, affecting the assets being traded which will be mitigated by performing specific functions.

4.2.1 History

The history of international trade chronicles notable events that have affected the trade between various countries.

In the era before the rise of the nation state, the term 'international' trade cannot be literally applied, but simply means trade over long distances; the sort of movement in goods which would represent international trade in the modern world.

4.2.2 Models

The following are noted models of international trade.

4.2.2.1 Adam Smith's model

Adam Smith displays trade taking place on the basis of countries exercising absolute advantage over one another.

4.2.2.2 Ricardian model

The Ricardian model focuses on comparative advantage, which arises due to differences in technology or natural resources. The Ricardian model does not directly consider factor endowments, such as the relative amounts of labor and capital within a country.

The Ricardian model is based on the following assumptions:

- Labor is the only primary input to production
- The relative ratios of labor at which the production of one good can be traded off for another differ between countries and governments

4.2.2.3 Heckscher–Ohlin model

In the early 1900s a theory of international trade was developed by two Swedish economists, Eli Heckscher and Bertil Ohlin. This theory has subsequently been known as the Heckscher–Ohlin model (H–O model). The results of the H–O model is that countries will produce and export goods that require resources (factors) which are relatively abundant and import goods that require resources which are in relative short supply.

In the Heckscher–Ohlin model the pattern of international trade is determined by differences in factor endowments. It predicts that countries will export those goods that make intensive use of locally abundant factors and will import goods that make intensive use of factors that are locally scarce. Empirical problems with the H–O model, such as the Leontief paradox, were noted in empirical tests by Wassily Leontief who found that the United States tended to export labor-intensive goods despite having an abundance of capital.

The H–O model makes the following core assumptions:

- Labor and capital flow freely between sectors
- The amount of labor and capital in two countries differ (difference in endowments)
- Technology is the same among countries (a long-term assumption)
- The tastes are the same

4.2.3 ***Applicability***

In 1953, Wassily Leontief published a study in which he tested the validity of the Heckscher-Ohlin theory. The study showed that the United States was more abundant in the capital compared to other countries, therefore the United States would export capital-intensive goods and import labor-intensive goods. Leontief found out that the United States' exports were less capital intensive than its imports.

After the appearance of Leontief's paradox, many researchers tried to save the Heckscher-Ohlin theory, either by new methods of measurement, or by new interpretations. Leamer emphasized that Leontief did not interpret H-O theory properly and claimed that with a right interpretation, the paradox did not occur. Brecher and Choudri found that, if Leamer was right, the American workers' consumption per head should be lower than the workers' world average consumption. Many textbook writers, including Krugman and Obstfeld and Bowen, Hollander and Viane, are negative about the validity of the H-O model. After examining the long history of empirical research, Bowen, Hollander and Viane concluded: "Recent tests of the factor abundance theory [H-O theory and its developed form into many-commodity and many-factor case] that directly examine the H-O-V equations also indicate the rejection of the theory."

In the specific factors model, labor mobility among industries is possible while capital is assumed to be immobile in the short run. Thus, this model can be interpreted as a short-run version of the Heckscher-Ohlin model. The "specific factors" name refers to the assumption that in the short run, specific factors of production such as physical capital are not easily transferable between industries. The theory suggests that if there is an increase in the price of a good, the owners of the factor of production specific to that good will profit in real terms.

Additionally, owners of opposing specific factors of production (i.e., labor and capital) are likely to have opposing agendas when lobbying for controls over immigration of labor. Conversely, both owners of capital and labor profit in real terms from an increase in the capital endowment. This model is ideal for understanding income distribution but awkward for discussing the pattern of trade.

4.2.4 New Trade Theory

New Trade Theory tries to explain empirical elements of trade that comparative advantage-based models above have difficulty with. These include the fact that most trades are between countries with similar factor endowment and productivity levels, and the large amount of multinational production (i.e., foreign direct investment) that exists. New Trade theories are often based on assumptions such as monopolistic competition and rising returns to scale. One result of these theories is the home-market effect, which asserts that, if an industry tends to cluster in one place because of returns to scale and if that industry faces high transportation costs, the industry will be located in the country with most of its demands, in order to minimize cost.

Although the new trade theory can explain the growing trend of trade volumes of intermediate goods, Krugman's explanation depends too much on the strict assumption that all firms are symmetrical, meaning that they all have the same production coefficients. Shiozawa, based on the much more general model, succeeded in giving a new explanation on why the traded volume increases for intermediate goods when the transport cost decreases.

4.2.5 Gravity model

The Gravity model of trade presents a more empirical study of trading patterns. The gravity model, in its basic form, predicts trade based on the distance between countries and the interaction of the countries' economic sizes. The model mimics the Newtonian law of gravity which also considers distance and physical size between two objects. The model has been proven to be empirically strong through econometric study .

4.2.6 Ricardian theory of international trade (modern developmental)

The Ricardian theory of comparative advantage became a basic constituent of neoclassical trade theory. Any undergraduate course in trade theory includes a presentation of Ricardo's example of a two-commodity, two-country model. A common representation of this model is made using an Edgeworth Box.

This model has been expanded to many-country and many-commodity cases. Major general results were obtained by McKenzie and Jones, including his famous formula. It is a theorem about the possible trade pattern for N-country N-commodity cases.

4.2.7 Contemporary theories

Ricardo's idea was even expanded to the case of continuum of goods by Dornbusch, Fischer, and Samuelson This formulation is employed for example by Matsuyama and others. These theories use a special property that is applicable only for the two-country case.

4.2.8 Neo-Ricardian trade theory

Inspired by PieroSraffa, a new strand of trade theory emerged and was named neo-Ricardian trade theory. The main contributors include Ian Steedman (1941–) and Stanley Metcalfe (1946–). They have criticized the neoclassical international trade theory, namely the Heckscher-Ohlin model on the basis that the notion of capital as primary factor has no method of measuring it before the determination of profit rate (thus trapped in a logical vicious circle). This was a second round of the Cambridge capital controversy, this time in the field of international trade.

The merit of neo-Ricardian trade theory is that input goods are explicitly included. This is in accordance with Sraffa's idea that any commodity is a product made by means of commodities. The limitation of their theory is that the study is restricted to small-country cases.

4.2.9 Traded intermediate goods

Ricardian trade theory ordinarily assumes that the labor is the unique input. This is a great deficiency as trade theory, for intermediate goods occupy the major part of the world international trade. Yeats found that 30% of world trade in manufacturing involves intermediate inputs. Bardhan and Jafee found that intermediate inputs occupy 37 to 38% of U.S. imports for the years 1992 and 1997, whereas the percentage of intra-firm trade grew from 43% in 1992 to 52% in 1997.

McKenzie and Jones emphasized the necessity to expand the Ricardian theory to the cases of trade inputs. In a famous comment McKenzie (1954, p. 179) pointed that "A moment's consideration will convince one that Lancashire would be unlikely to produce cotton cloth if the cotton had to be grown in England."Paul Samuelson coined a term *Sraffa bonus* to name the gains from trade of inputs.

4.2.10 ***Ricardo-Sraffa trade theory***

Economist John S. Chipman observed in his survey that McKenzie stumbled upon the questions of intermediate products and postulated that "introduction of trade in intermediate product necessitates a fundamental alteration in classical study ". It took many years until Shiozawa succeeded in removing this deficiency. The Ricardian trade theory was now constructed in a form to include intermediate input trade for the most general case of many countries and many goods. Chipman called this the Ricardo-Sraffa trade theory.

Based on an idea of Takahiro Fujimoto, who is a specialist in automobile industry and a philosopher of the international competitiveness, Fujimoto and Shiozawa developed a discussion in which how the factories of the same multi-national firms compete between them across borders. International *intra-firm competition* reflects a really new aspect of international competition in the age of so-called *global competition*.

4.2.11 ***International Production Fragmentation Trade Theory***

Fragmentation and International Trade Theory widens the scope for "application of Ricardian comparative advantage". In his chapter entitled *Li & Fung, Ltd.: An agent of global production* (2001), Cheng used Li & Fong Ltd as a case study in the international production fragmentation trade theory through which producers in different countries allocate a specialized slice or segment of the value chain of the global production. Alplaces are determined based on on "technical feasibility" and the ability to keep the lowest final price possible for each product.

An example of the fragmentation theory of international trade is Li and Fung's garment sector network with yarn purchased in South Korea, woven and dyed in Taiwan, the fabric cut in Bangladesh, the pieces assembled in Thailand and the final product sold in the United States and Europe to major brands. In 1995 Li & Fung Ltd purchased Inchcape Buying Services, an established British trading company and widely expanded production in Asia. Li & Fung supply dozens of major retailers, including Wal-Mart Stores, Inc., branded as Walmart.

4.3 **Major Trade Blocks NAFTA, EEC, ASEAN**

4.3.1 **NAFTA**

The **North American Free Trade Agreement** (**NAFTA**; French: *Accord de libre-échangenord-américain*, *ALÉNA*; Spanish: *Tratado de LibreComercio de América del Norte*, *TLCAN*) is an agreement signed by Canada, Mexico, and the United States, creating a trilateral trade bloc in North America. The agreement came into force on January 1, 1994. It superseded the Canada–United States Free Trade Agreement between the U.S. and Canada. In terms of combined purchasing power parity GDP of its members, as of 2007 the trade bloc is the largest in the world and second largest by nominal GDP comparison.

NAFTA has two supplements: the North American Agreement on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC).

4.3.1.1 Negotiation and U.S. ratification

Following diplomatic negotiations dating back to 1986 among the three nations, the leaders met in San Antonio, Texas, on December 17, 1992, to sign NAFTA. U.S. President George H. W. Bush, Canadian Prime Minister Brian Mulroney and Mexican President Carlos Salinas, each responsible for spearheading and promoting the agreement, ceremonially signed it. The signed agreement then needed to be ratified by each nation's legislative or parliamentary branch.

Before the negotiations were finalized, Bill Clinton came into office in the U.S. and Kim Campbell in Canada, and before the agreement became law, Jean Chrétien had taken office in Canada.

The proposed Canada-U. S. Trade agreement had been very controversial and divisive in Canada, and the 1988 Canadian election was fought almost exclusively on that issue. In that election, more Canadians voted for anti-free trade parties (the Liberals and the New Democrats) but the split caused more seats in parliament to be won by the pro-free trade Progressive Conservatives (PCs). Mulroney and the PCs had a parliamentary majority and were easily able to pass the Canada-US FTA and NAFTA bills. However, he was replaced as Conservative leader and prime minister by Kim Campbell. Campbell led the PC party in the 1993 election where they were decimated by the Liberal Party under Jean Chrétien, who had campaigned on a promise to renegotiate or abrogate NAFTA; however, Chrétien subsequently negotiated two supplemental agreements with the new US president. In the US, Bush, who had worked to "fast track" the signing prior to the end of his term, ran out of time and had to pass the required ratification and signing into law to incoming president Bill Clinton. Prior to sending it to the United States Senate, Clinton introduced clauses to protect American workers and allay the concerns of many House members. It also required US partners to adhere to environmental practices and regulations similar to its own.

With much consideration and emotional discussion, the House of Representatives approved NAFTA on November 17, 1993, 234-200. The agreement's supporters included 132 Republicans and 102 Democrats. NAFTA passed the Senate 61-38. Senate supporters were 34 Republicans and 27 Democrats. Clinton signed it into law on December 8, 1993; it went into effect on January 1, 1994. Clinton, while signing the NAFTA bill, stated that "NAFTA means jobs. American jobs, and good-paying American jobs. If I didn't believe that, I wouldn't support this agreement."

4.3.1.2 Provisions

The goal of NAFTA was to eliminate barriers to trade and investment between the U.S., Canada and Mexico. The implementation of NAFTA on January 1, 1994 brought the immediate elimination of tariffs on more than one-half of Mexico's exports to the U.S. and more than one-third of U.S. exports to Mexico. Within 10 years of the implementation of the agreement, all U. S. -Mexico tariffs would be eliminated except for some U.S. agricultural exports to Mexico that were to be phased out within 15 years. Most U.S.-Canada trade was already duty free. NAFTA also seeks to eliminate non-tariff trade barriers and to protect the intellectual property right of the products.

In the area of intellectual property, the North American Free Trade Agreement Implementation Act made some changes to the Copyright law of the United States, foreshadowing the Uruguay Round Agreements

Act of 1994 by restoring copyright (within NAFTA) on certain motion pictures which had entered the public domain.

4.3.1.3 Mechanisms

Chapter 52 provides a procedure for the interstate resolution of disputes over the application and interpretation of NAFTA. It was modeled after Chapter 69 of the Canada-United States Free Trade Agreement.

NAFTA's effects, both positive and negative, have been quantified by several economists, whose findings have been reported in publications such as the World Bank's *Lessons from NAFTA for Latin America and the Caribbean*, *NAFTA's Impact on North America*, and *NAFTA Revisited* by the Institute for International Economics.

4.3.1.4 Trade

The agreement opened the door for open trade, ending tariffs on various goods and services, and implementing equality between Canada, USA, and Mexico. NAFTA has allowed agricultural goods such as eggs, corn, and meats to be tariff-free. This allowed corporations to trade freely and import and export various goods on a North American scale.

4.3.1.5 Trade balances

The US goods trade deficit with NAFTA was $94.6 billion in 2010, a 36.4% increase ($25 billion) over 2009.

The US goods trade deficit with NAFTA accounted for 26.8% of the overall U.S. goods trade deficit in 2010.

The US had a services trade surplus of $28.3 billion with NAFTA countries in 2009 (the latest data available).

4.3.1.6 Investment

The US foreign direct investment (FDI) in the NAFTA Countries (stock) was $327.5 billion in 2009 (latest data available), up 8.8% from 2008.

The US direct investment in NAFTA countries is in nonbank holding companies, and in the manufacturing, finance/insurance, and mining sectors.

The foreign direct investment, of Canada and Mexico in the United States (stock) was $237.2 billion in 2009 (the latest data available), up 16.5% from 2008.

4.3.1.7 Industry

Maquiladoras (Mexican factories that take in imported raw materials and produce goods for export) have become the landmark of trade with Mexico. These are plants that moved to this region from the United States, hence the debate over the loss of American jobs. Hufbauer's (2005) book shows that income in the maquiladora sector has increased 15.5% since the implementation of NAFTA in 1994. Other sectors now benefit from the free trade agreement, and the share of exports from non-border states has increased in the last five years while the share of exports from maquiladora-border states has decreased. This has allowed for the rapid growth of non-border metropolitan areas, such as Toluca, León and Puebla; all three larger in population than Tijuana, Ciudad Juárez, and Reynosa.

4.3.1.8 Environment

Securing U.S. congressional approval for NAFTA would have been impossible without addressing public concerns about NAFTA's environmental impact. The Clinton administration negotiated a side agreement on the environment with Canada and Mexico, the North American Agreement on Environmental Cooperation (NAAEC), which led to the creation of the Commission for Environmental Cooperation (CEC) in 1994. To alleviate concerns that NAFTA, the first regional trade agreement between a developing country and two developed countries, would have negative environmental impacts, the CEC was given a mandate to conduct ongoing*ex post* environmental assessment of NAFTA.

In response to this mandate, the CEC created a framework for conducting environmental studies of NAFTA, one of the first *ex post* frameworks for the environmental assessment of trade liberalization. The framework was designed to produce a focused and systematic body of evidence with respect to the initial hypotheses about NAFTA and the environment, such as the concern that NAFTA would create a "race to the bottom" in environmental regulation among the three countries, or the hope that NAFTA would pressure governments to increase their environmental protection mechanisms. The CEC has held four symposia using this framework to evaluate the environmental impacts of NAFTA and has commissioned 47 papers on this subject. In keeping with the CEC's overall strategy of transparency and public involvement, the CEC commissioned these papers from leading independent experts.

Overall, none of the initial hypotheses were confirmed. NAFTA did not inherently present a systemic threat to the North American environment, as was originally feared. NAFTA-related environmental threats instead occurred in specific areas where government environmental policy, infrastructure, or mechanisms, were unprepared for the rising scale of production under trade liberalization. In some cases, environmental policy was neglected in the wake of trade liberalization; in other cases, NAFTA's measures for investment protection, such as Chapter 11, and measures against non-tariff trade barriers, threatened to discourage more vigorous environmental policy. The most serious overall increases in pollution due to NAFTA were found in the base metals sector, the Mexican petroleum sector, and the transportation equipment sector in the United States and Mexico, but not in Canada.

4.3.1.9 Agriculture

From the earliest negotiation, agriculture was (and still remains) a controversial topic within NAFTA, as it has been with almost all free trade agreements that have been signed within the WTO framework. Agriculture is the only section that was not negotiated trilaterally; instead, three separate agreements were signed between each pair of parties. The Canada–U. S. The agreement contains significant restrictions and tariff quotas on agricultural products (mainly sugar, dairy, and poultry products), whereas the Mexico–U. S. Pact allows for a wider liberalization within a framework of phase-out periods (it was the first North–South FTA on agriculture to be signed).

The overall effect of the Mexico–U. S. Agricultural agreement is a matter of dispute. Mexico did not invest in the infrastructure necessary for competition, such as efficient railroads and highways, which resulted in more difficult living conditions in the country's poor. Mexico's agricultural exports increased

9.4 percent annually between 1994 and 2001, while imports increased by only 6.9 percent a year during the same period.

One of the most affected agricultural sectors is the meat industry. Mexico has gone from a small-key player in the pre-1994 U.S. export market to the 2nd largest importer of U.S. agricultural products in 2004, and NAFTA may be credited as a major catalyst for this change. The allowance of free trade removed the hurdles that impeded business between the two countries. As a result, Mexico has provided a growing market for meat for the U.S., leading to an increase in sales and profits in the U.S. meat industry. This coincides with a noticeable increase in Mexican per capita GDP that has created large changes in meat consumption patterns, implying that Mexicans can now afford to buy more meat and thus per capita meat consumption has grown.

Production of corn in Mexico has increased since NAFTA's implementation. However, internal corn demand has increased beyond Mexico's sufficiency, and imports have become necessary, far beyond the quotas Mexico had originally negotiated. Zahniser& Coyle has also pointed out that corn prices in Mexico, adjusted for international prices, have drastically decreased, yet through a program of subsidies expanded by former president Vicente Fox, production has remained stable since 2000.

In a study published in the August 2008 issue of the *American Journal of Agricultural Economics*, NAFTA has increased U.S. agricultural exports to Mexico and Canada even though most of this increase occurred a decade after its ratification. The study focused on the effects that gradual "phase-in" periods in regional trade agreements, including NAFTA, have on trade flows. Most of the increase in members' agricultural trade, which was only recently brought under the purview of the World Trade Organization, was due to very high trade barriers before NAFTA or other regional trade agreements.

4.3.1.10 Mobility of persons

According to the Department of Homeland Security Yearbook of Immigration Statistics, during fiscal year 2006 (i.e., October 2005 through September 2006), 73,880 foreign professionals (64,633 Canadians and 9,247 Mexicans) were admitted into the United States for temporary employment under NAFTA (i.e., in the TN status). Additionally, 17,321 of their family members (13,136 Canadians, 2,904 Mexicans, as well as a number of third-country nationals married to Canadians and Mexicans) entered the U.S. in the treaty national's dependent (TD) status. Because DHS counts the number of the new I-94 arrival records filled at the border, and the TN-1 admission is valid for three years, the number of non-immigrants in TN status present in the U.S. at the end of the fiscal year is approximately equal to the number of admissions during the year. (A discrepancy may be caused by some TN entrants leaving the country or changing status before their three-year admission period has expired, while other immigrants admitted earlier may change their status *to* TN or TD, or extend TN status granted earlier).

Canadian authorities estimated that, as of December 1, 2006, a total of 24,830 U.S. citizens and 15,219 Mexican citizens were present in Canada as "foreign workers". These numbers include both entrants under the NAFTA agreement and those who have entered under other provisions of the Canadian immigration law. New entries of foreign workers in 2006 were 16,841 (U.S. citizens) and 13,933 (Mexicans).

4.3.2 EEC

The **European Economic Community** (**EEC**) was an international organization created by the Treaty of Rome of 1957.

Its aim was to bring about economic integration, including a common market, among its six founding members: Belgium, France, Italy, Luxembourg, the Netherlands and West Germany. The EEC was also known as the **Common Market** in the English-speaking world and sometimes referred to as the **European Community** even before it was officially renamed as such in 1993.

It gained a common set of institutions along with the European Coal and Steel Community (ECSC) and the European Atomic Energy Community (EURATOM) as one of the European Communities under the 1965 Merger Treaty (Treaty of Brussels).

Upon the entry into force of the Maastricht Treaty in 1993, the EEC was renamed the *European Community* (*EC*) to reflect that it covered a wider range of policy. This was also when the three European Communities, including the EC, were collectively made to constitute the first of the three pillars of the European Union (EU), which the treaty also founded. The EC existed in this form until it was abolished by the 2009 Treaty of Lisbon, which merged the EU's former pillars and provided that the EU would "replace and succeed the European Community."

4.3.2.1 Background

In 1951, the Treaty of Paris was signed, creating the European Coal and Steel Community (ECSC). This was an international community based on supranationalism and international law, designed to help the economy of Europe and prevent future war by integrating its members.

With the aim of creating a federal Europe to further communities were proposed: a European Defense Community (EDC) and a European Political Community (EPC). While the treaty for the latter was being drawn up by the Common Assembly, the ECSC parliamentary chamber, the EDC was rejected by the French Parliament. President Jean Monnet, a leading figure behind the communities, resigned from the High Authority in protest and began work with alternative communities, based on economic integration rather than political integration. After the Messina Conference in 1955, Paul Henri Spaak was given the task to prepare a report on the idea of a customs union. The so-called Spaak Report of the Spaak Committee formed the cornerstone of the intergovernmental negotiations at Val Duchesse castle in 1956. Together with the Ohlin Report the Spaak Report would provide the basis of the Treaty of Rome.

In 1956, Paul Henri Spaak led the Intergovernmental Conference on the Common Market and Euratom at the Val Duchesse castle, which prepared for the Treaty of Rome in 1957. The conference led to the signature, on 25 March 1957, of the Treaty of Rome establishing a European Economic Community.

4.3.2.2 Creation and early years

The resulting communities were the European Economic Community (EEC) and the European Atomic Energy Community (EAEC or Euratom). These were markedly less supranational than the previous communities, due to protests from some countries that their sovereignty was being infringed (however there would still be concerned with the behavior of the Hallstein Commission). The first formal meeting of the Hallstein Commission, was held on 16 January 1958 at the Chateau de Val-Duchesse. The EEC (direct ancestor of the modern Community) was to create a customs union while Euratom would promote co-operation in the nuclear power sphere. The EEC rapidly became the most important of these and expanded its actions . One of the first important accomplishment of the EEC was the establishment (1962) of common price levels for agricultural products. In 1968, internal tariffs (tariffs on trade between member nations) were removed on certain products.

Another crisis was triggered in regard to proposals for the financing of the Common Agricultural Policy, which came into force in 1962. The transitional period whereby decisions were made by unanimity had come to an end, and majority-voting in the Council had taken effect. Then-French President Charles de Gaulle's opposition to supranationalism and fear of the other members challenging the CAP led to an "empty chair policy" whereby French representatives were withdrawn from the European institutions until the French veto was reinstated. Eventually, a compromise was reached with the Luxembourg compromise on 29 January 1966 whereby a gentlemen's agreement permitted members to use a veto on areas of national interest.

On 1 July 1967 when the Merger Treaty came into operation, combining the institutions of the ECSC and Euratom into that of the EEC, they already shared a Parliamentary Assembly and Courts. Collectively they were known as the *European Communities*. Future treaties granted the community new powers beyond simple economic matters which had achieved a high level of integration. As it got closer to the goal of political integration and a peaceful and united Europe, what Mikhail Gorbachev described as a *Common European Home*.

4.3.2.3 Enlargement and elections

The 1960s saw the first attempts at enlargement. In 1961, Denmark, Ireland, Norway and the United Kingdom applied to join the three Communities. However, President Charles de Gaulle saw British membership as a Trojan horse for US influence and vetoed membership, and the applications of all four countries were suspended.

The four countries resubmitted their applications on 11 May 1967 and with Georges Pompidou succeeds Charles de Gaulle as French president in 1969, the veto was lifted. Negotiations began in 1970 under the pro-European government of Edward Heath, who had to deal with disagreements relating to the Common Agricultural Policy and the UK's relationship with the Commonwealth of Nations. Nevertheless, two years later the accession treaties were signed and all but Norway acceded to the Community (Norway rejected membership in a referendum) from 1 January 1973.

The Treaties of Rome had stated that the European Parliament must be directly elected, however this required the Council to agree on a common voting system first. The Council procrastinated on the issue and the Parliament remained appointed, French President Charles de Gaulle was particularly active in blocking the development of the Parliament, with it only being granted Budgetary powers following his resignation.

Parliament pressured for agreement and on 20 September 1976 the Council agreed part of the necessary instruments for election, deferring the details on electoral systems which remain buried to this day. During the tenure of President Jenkins, in June 1979, the elections were held in all the then-members. The new Parliament, galvanized by direct election and new powers, started working full-time and became more active than the previous assemblies.

Shortly after its election, Parliament became the first Community institution to propose that the Community adopt the flag of Europe. The European Council agreed to this and adopted the Symbols of Europe as those of the Community in 1984. The European Council, or European summit, had developed since the 1960s as an informal meeting of the Council at the level of heads of state. It had originated from then-French President Charles de Gaulle's resentment at the domination of supranational institutions (e.g. the Commission) over the integration process. It was mentioned in the treaties for the first time in the Single European Act.

4.3.2.4 Towards Maastricht

Greece applied to join the community on 12 June 1975, following the restoration of democracy, and joined on 1 January 1981. Following on from Greece, and after their own democratic restoration, Spain and Portugal applied to the communities in 1977 and joined together on 1 January 1986. In 1987 Turkey formally applied to join the Community and began the longest application process for any country.

With the prospect of further enlargement, and a desire to increase areas of co-operation, the Single European Act was signed by the foreign ministers on the 17 and 28 February 1986 in Luxembourg and the Hague respectively. In a single document it dealt with reform of institutions, extension of powers, foreign policy cooperation and the single market. It came into force on 1 July 1987. The act was followed by work on what would be the Maastricht Treaty, which was agreed on 10 December 1991, signed the following year and coming into force on 1 November 1993 establishing the EU.

4.3.2.5 European Community

The EU absorbed the European Communities as one of its three pillars. The EEC's areas of actions were enlarged and were renamed the European Community, continuing to follow the supranational structure of the EEC. The EEC institutions became those of the EU, however the Court, Parliament and Commission had only limited input in the new pillars, as they worked on a more intergovernmental system than the European Communities. This is reflected in the names of the institutions, the Council is formally the "Council of the *European Union*" while the Commission is formally the "Commission of the *European Communities*".

However, after the Treaty of Maastricht, Parliament gained a much bigger role. Maastricht brought in the codecision procedure, which gave it equal legislative power with the Council on Community matters. Hence, with the great powers of the supranational institutions and the operation of Qualified Majority Voting in the Council, the Community pillar could be described as a far more federal method of decision making.

The Treaty of Amsterdam transferred responsibility for free movement of persons (e.g. Visas, illegal immigration, asylum) from the Justice and Home Affairs (JHA) pillar of the European Community (JHA was renamed Police and Judicial Co-operation in Criminal Matters (PJCC) as a result). Both Amsterdam and the Treaty of Nice also extended codecision procedure to nearly all policy areas, giving Parliament equal power to the Council in the Community.

In 2002, the Treaty of Paris which established the ECSC expired, having reached its 50-year limit (as the first treaty, it was the only one with a limit). No attempt was made to renew its mandate; instead, the Treaty of Nice transferred certain of its elements to the Treaty of Rome and hence its work continued as part of the EC area of the European Community's remit.

After the entry into force of the Treaty of Lisbon in 2009 the pillar structure ceased to exist. The European Community, together with its legal personality, was transferred to the newly consolidated European Union which merged in the other two pillars (however Euratom remained distinct). This was originally proposed under the European Constitution but that treaty failed ratification in 2005.

4.3.2.6 Aims and achievements

The main aim of the EEC, as stated in its preamble, was to "preserve peace and liberty and to lay the foundations of an ever closer union among the peoples of Europe". Calling for balanced economic growth, this was to be accomplished through:

1. The establishment of a customs union with a common external tariff
2. Common policies for agriculture, transportation and trade
3. Enlargement of the EEC to the rest of Europe

For the customs union, the treaty provided for a 10% reduction in custom duties and up to 20% of global import quotas. Progress on the customs union proceeded much faster than the twelve years planned. However, France faced some setbacks due to their war with Algeria.

4.3.2.7 Members

The six states that founded the EEC and the other two Communities were known as the "inner six" (the "outer seven" were those countries who formed the European Free Trade Association). The six were France, West Germany, Italy and the three Benelux countries: Belgium, the Netherlands and Luxembourg. The first enlargement was in 1973, with the accession of Denmark, Ireland and the United Kingdom. Greece, Spain and Portugal joined in the 1980s. The former East Germany became part of the EEC upon German reunification in 1990. Following the creation of the EU in 1993, it has enlarged to include a further fifteen countries by 2007.

Member states are represented in some form in each institution. The Council is also composed of one national minister who represents their national government. Each state also has a right to one European Commissioner each, although in the European Commission they are not supposed to represent their national interest but that of the Community. Prior to 2004, the larger members (France, Germany, Italy and the United Kingdom) have had two Commissioners. In the European Parliament, members are allocated a set number seats related to their population, however these (since 1979) have been directly elected and they sit according to political allegiance, not national origin. Most other institutions, including the European Court of Justice, have some form of national division of its members.

4.3.2.8 Institutions

There were three political institutions which held the executive and legislative power of the EEC, plus one judicial institution and a fifth body created in 1975. These institutions (except for the Auditors) were created in 1957 by the EEC but from 1967 onwards they applied to all three Communities. The Council represents governments, the Parliament represents the citizens and the Commission represents the European interest. Essentially, the Council, Parliament or another party place a request for legislation to the Commission. The Commission then drafts this and presents it to the Council for approval and the Parliament for an opinion (in some cases it had a veto, depending upon the legislative procedure in use). The Commission's duty is to ensure it is implemented by dealing with the day-to-day running of the Union and taking others to Court if they fail to comply. After the Maastricht treaty in 1993, these institutions became those of the European Union, though limited in some areas due to the pillar structure. Despite this, Parliament in particular has gained more power over legislation and security of the Commission. The Court was the highest authority in the law, settling legal disputes in the Community, while the Auditors had no power but to investigate.

4.3.3 ASEAN

The **Association of Southeast Asian Nations** is a geopolitical and economic organization of ten countries located in Southeast Asia, which was formed on 8 August 1967 by Indonesia, Malaysia, the Philippines, Singapore and Thailand. Since then, membership has expanded to include Brunei, Burma (Myanmar), Cambodia, Laos, and Vietnam. Its aims include accelerating economic growth, social progress, cultural development among its members, protection of regional peace and stability, and opportunities for member countries to discuss differences peacefully.

ASEAN covers a land area of 4.46 million km², which is 3% of the total land area of Earth, and has a population of approximately 600 million people, which is 8.8% of the world's population. The sea area of ASEAN is about three times larger than its land counterpart. In 2011, its combined nominal GDP had grown to more than US$ 2 trillion. If ASEAN were a single entity, it would rank as the eighth largest economy in the world.

4.3.3.1 History

ASEAN was preceded by an organization called the **Association of Southeast Asia**, commonly called **ASA**, an alliance consisting of the Philippines, Malaysia and Thailand that was formed in 1961. The bloc itself, however, was established on 8 August 1967, when foreign ministers of five countries – Indonesia, Malaysia, the Philippines, Singapore, and Thailand – met at the Thai Department of Foreign Affairs building in Bangkok and signed the ASEAN Declaration, more commonly known as the Bangkok Declaration. The five foreign ministers – Adam Malik of Indonesia, Narciso Ramos of the Philippines, Abdul Razak of Malaysia, S. Rajaratnam of Singapore, and ThanatKhoman of Thailand – are considered the organization's Founding Fathers.

The motivations for the birth of ASEAN were so that its members' governing elite could concentrate on nation building, the common fear of communism, reduced faith in or mistrust of external powers in the 1960s, and a desire for economic development.

The bloc grew when Brunei Darussalam became the sixth member on 8 January 1984, barely a week after gaining independence on 1 January.

4.3.3.2 Continued expansion

On 28 July 1995, Vietnam became the seventh member. Laos and Myanmar (Burma) joined two years later on 23 July 1997. Cambodia was to have joined together with Laos and Burma, but was deferred due to the country's internal political struggle. The country later joined on 30 April 1999, following the stabilization of its government.

During the 1990s, the bloc experienced an increase in both membership and drive for further integration. In 1990, Malaysia proposed the creation of an East Asia Economic Caucus comprising the then members of ASEAN as well as the People's Republic of China, Japan, and South Korea, with the intention of counterbalancing the growing influence of the United States in the Asia-Pacific Economic Cooperation (APEC) and in the Asian region as a whole. This proposal failed, however, because of heavy opposition from the United States and Japan. Despite this failure, member states continued to work for further integration and ASEAN Plus Three was created in 1997.

In 1992, the Common Effective Preferential Tariff (CEPT) scheme was signed as a schedule for phasing tariffs and as a goal to increase the *region's competitive advantage as a production base geared for the world market*. This law would act as the framework for the ASEAN Free Trade Area. After the East Asian Financial Crisis of 1997, a revival of the Malaysian proposal was established in Chiang Mai, known as the Chiang Mai Initiative, which calls for better integration between the economies of ASEAN as well as the ASEAN Plus Three countries (China, Japan, and South Korea).

Aside from improving each member state's economies, the bloc also focused on peace and stability in the region. On 15 December 1995, the Southeast Asian Nuclear-Weapon-Free Zone Treaty was signed with the intention of turning Southeast Asia into a Nuclear-Weapon-Free Zone. The treaty took effect on 28 March 1997 after all but one of the member states have ratified it. It became fully effective on 21 June 2001, after the Philippines ratified it, effectively banning all nuclear weapons in the region.

4.3.3.3 East Timor and Papua New Guinea

East Timor submitted a letter of application to be the eleventh member of ASEAN at the summit in Jakarta in March 2011. Indonesia has shown a warm welcome to East Timor.

Papua New Guinea was accorded Observer status in 1976 and Special Observer status in 1981. Papua New Guinea is a Melanesian state. ASEAN embarked on a program of economic cooperation following the Bali Summit of 1976. This floundered in the mid-1980s and was only revived around 1991 due to a Thai proposal for a regional free trade area.

4.3.3.4 Environment

At the turn of the 21st century, issues shifted to include a regional approach to the environment. The organization started to discuss environmental agreements. These included the signing of the ASEAN Agreement on Transboundary Haze Pollution in 2002 as an attempt to control haze pollution in Southeast Asia. Unfortunately, this was unsuccessful due to the outbreaks of the 2005 Malaysian haze and the 2006 Southeast Asian haze. Other environmental treaties introduced by the organization include the Cebu Declaration on East Asian Energy Security, the ASEAN Wildlife Enforcement Network in 2005, and the Asia-Pacific Partnership on Clean Development and Climate, both of which are responses to the potential effects of climate change. Climate change is of current interest.

Through the Bali Concord II in 2003, ASEAN has subscribed to the notion of democratic peace, which means all member countries believe democratic processes will promote regional peace and stability. Also, the non-democratic members all agreed that it was something all member states should aspire to.

4.3.3.5 ASEAN Plus Three

Leaders of each country, particularly Mahathir Mohamad of Malaysia, felt the need to further integrate the region. Beginning in 1997, the bloc began creating organizations within its framework with the intention of achieving this goal. ASEAN Plus Three was the first of these and was created to improve existing ties with the People's Republic of China, Japan, and South Korea. This was followed by the even larger East Asia Summit, which now includes these countries as well as India, Australia, New Zealand, United States and Russia. This new grouping acted as a prerequisite for the planned East Asia Community, which was supposedly patterned after the now-defunct European Community. The ASEAN Eminent Persons Group was created to study the possible successes and failures of this policy as well as the possibility of drafting an ASEAN Charter.

In 2006, ASEAN was given observer status at the United Nations General Assembly. As a response, the organization awarded the status of "dialogue partner" to the United Nations.

4.3.3.6 Free Trade

In 2007, ASEAN celebrated its 40th anniversary since its inception, and 30 years of diplomatic relations with the United States. On 26 August 2007, ASEAN stated that it aims to complete all its free trade agreements with China, Japan, South Korea, India, Australia and New Zealand by 2013, in line with the establishment of the ASEAN Economic Community by 2015. In November 2007 the ASEAN members signed the ASEAN Charter, a constitution governing relations among the ASEAN members and establishing ASEAN itself as an international legal entity. During the same year, the Cebu Declaration on East Asian Energy Security was signed in Cebu on 15 January 2007, by ASEAN and the other members of the EAS (Australia, People's Republic of China, India, Japan, New Zealand, South Korea), which promotes energy security by finding energy alternatives to conventional fuels.

On 27 February 2009 a Free Trade Agreement with the ASEAN regional block of 10 countries and Australia and its close partner in New Zealand was signed, it is estimated that this FTA would boost aggregate GDP across the 12 countries by more than US$48 billion over the period 2000–2020. ASEAN members together with the group's six major trading partners – Australia, China, India, Japan, New Zealand and South Korea – are slated to begin the first round of negotiations on 26-28 February 2013 in Bali, Indonesia, on the establishment of the Regional Comprehensive Economic Partnership.

4.3.3.7 The ASEAN Way

Since the post-independence phases of Southeast Asian states, efforts were made to implement regional foreign policies, but with a unifying focus to refrain from interference in the domestic affairs of member states.

There was a move to unify the region under what was called the 'ASEAN Way' based on the ideals of non-interference, informality, minimal institutionalisation, consultation and consensus, non-use of force and non-confrontation. ASEAN members (especially Singapore) approved of the term 'ASEAN Way' to describe a regional method of multilateralism.

Thus the signing of the Treaty of Amity and Cooperation in Southeast Asia adopted fundamental principles:

- Mutual respect for the independence, sovereignty, equality, territorial integrity, and national identity of all nations
- The right of every State to lead its national existence free from external interference, subversion or coercion
- Non-interference in internal affairs
- Settlement of differences or disputes in a peaceful manner
- Renunciation of the threat or use of force
- Effective regional cooperation

The 'ASEAN way' is said to contribute durability and longevity within the organization, by promoting regional identity and enhancing a spirit of mutual confidence and cooperation. ASEAN agreements are negotiated in a close, interpersonal process. The process of consultations and consensus is designed to engender a democratic approach to decision making. These leaders are wary of any effort to legitimize efforts to undermine their nation or contain regional co-operation.

4.3.3.8 Critical reception

The ASEAN way can be seen as divergent from the contextual contemporary political reality at the formative stages of the association. A critical distinction is made by AmitavAcharya, that the 'ASEAN Way' indicates "a process of 'regional interactions and cooperation based on discreteness, informality, consensus building and non-confrontational bargaining styles' that contrasts with 'the adversarial posturing, majority vote and other legalistic decision-making procedures in Western multilateral organizations'".

However, critics argue that the ASEAN Way serves as the major stumbling-block to it becoming a true diplomacy mechanism. Due to the consensus-based approach every member has a veto, so contentious issues must remain unresolved until agreements can be reached. Moreover, it is claimed that member nations are directly and indirectly advocating that ASEAN be more flexible and allow discourse on the internal affairs of member countries.

Additionally, the preference for informal discussions to adversarial negotiations limits the leverage of diplomatic solutions within ASEAN.

Michael Yahuda, explains, in his book *International Politics of the Asia Pacific (2003)* second and revised edition, the limitations of the ASEAN way. In summary of his argument, unlike the European Union, 'the ASEAN Way' has made ASEAN members never aspired to an economic and political union. It was designed to sustain the independence and sovereignty of member states and to encourage regional and national stability. ASEAN differed in assessment of external threat and they operated within conditions in which legality and the rule of law were not generally consolidated within member states. ASEAN wasn't a rule making body subjecting its members to the discipline of adhering its laws and regulations. It was operated through consensus and informality. Also, the member states avoided confronting certain issues if they were to result in conflicts.

4.4 **Effect of Globalization on Developing Countries**

Financial and industrial globalization is rising substantially and is creating new opportunities for both industrialized and developing countries. The largest impact has been in developing countries, who now are able to attract foreign investors and foreign capital. This has led to both positive and negative effects for those countries.

4.4.1 Increased Standard of Living

Economic globalization gives the governments of developing nations access to foreign lending. When these funds are used on infrastructure including roads, health care, education, and social services, the standard of living in the country increases. If the cash is used only selectively, however, not all citizens will participate in the benefits.

4.4.2 Access to New Markets

Globalization leads to freer trade between countries. This is one of its largest benefits to developing nations. Home grown industries see trade barriers fall and have access to a much wider international market. The growth this generates allows companies to develop new technologies and produce new products and services.

4.4.3 Widening Disparity in Incomes

While an influx of foreign companies and foreign capital creates a reduction in overall unemployment and obvious why, it can also increase the wage gap between those who are educated and those who are not. Over the long term, education levels will rise as the financial health of developing countries rise, but in the short term, some of the poor will become poorer. Not everyone will participate in an elevation of living standards.

4.4.4 Decreased Employment

The influx of foreign companies into developing countries increases employment in many sectors, especially for skilled workers. However, improvements in technology come with the new businesses and that technology spreads to domestic companies. Automation in the manufacturing and agricultural sectors lessens the need for unskilled labor and unemployment rises in those sectors. If there is no infrastructure to help the unemployed train for the globalized economy, social services in the country may become strained trying to care for the new underclass.

Review Questions

1. Define the major transportation route?
2. Explain the International Trade?
3. Explain the Major Trade Blocks?
4. Explain the Effect of Globalization on Developing Countries?

Discussion Questions

Discuss the role of trading blocks in economic development?

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