UNIT 3 IMPACT OF AGRICULTURE ON ENVIRONMENT

Structure

3.1 INTRODUCTION

No industry is more vital to our present and future well being than agriculture and few have shown the unsustainability of its existing practices. In Unit 1 of this course you have read about the evolution of agriculture, which humankind has been engaged in for thousands of years. However, earlier agriculture was closely knit at local level. All farm inputs were locally available. Livestock provided milk and farm power. The dung from livestock and agricultural residues were used as farmyard manure, which replenished soil nutrients depleted by the crops.

The high yielding modern intensive farming systems have shown the amazing ability of human beings to adapt and control the agro-ecosystems. They have been able to remove or diminish the limitations nature has put on productivity, and to provide a more favourable environment for crop growth, increasing dramatically their productive potential.

However, the problem started with the rise in population, and the consequent need for more food. For producing more food in the same land area, synthetic fertilizers came in. For protection against the damage caused by insects and pests, pesticides appeared on the scene. More food production also led to more withdrawal of water from the limited available sources leading to high water table in ground water, salinization etc.

The high input intensive agriculture has solved the food and nutrient problem for the growing population but agricultural land has continued to shrink and environmental threat to the region has become a reality. Thus agriculture has a major influence on the environment as it accounts for a large portion of the land use and water use patterns.

In 2010, the population of the developing countries of Asia is expected to become 3729 million. The demand for food is expected to be around 959 million tons and the production is estimated to be around 927 million tons leaving a gap of 32 million tons. It is estimated that though the region may be able to meet the demand without excessive imports by 2010, over 200 million people would still suffer from chronic under-nutrition, for crop yields per ha of land are declining every year alarmingly.

The slow down in agricultural output is due to several factors and one of the significant ones is that the land is becoming unable to support the burden of intensive agriculture as the environmental foundations of sustainable agriculture that is, land, water, biodiversity and forests are being damaged increasingly.

Agriculture has both primary and secondary environmental effects. A primary effect is also called **on-site** effect, i.e., an effect on the area where agriculture takes place. A secondary effect or **off-site** effect is an effect on an environment away from the agricultural site. The impact of agriculture on the environment can be **local,** which includes erosion, loss of soil, and increase in sedimentation in the local rivers; **regional** that results from the combined effects of agricultural practices in the same large area; or **global** which includes climatic changes as well as potentially extensive changes in the chemical cycles. In this unit we will discuss the impact of modern agricultural practices on natural resources and climate changes.

Objectives

After studying this unit, you should be able to:

- explain how agriculture is affecting the environment;
- identify the practices which are depleting the water resources and causing salinization and ground water pollution;
- explain the effects of pesticides and pesticide residues in fruits, vegetables, milk, fish, eggs etc., on the environment;
- explain how agriculture is affecting bio-diversity;
- identify practices which lead to soil degradation;
- explain whether agriculture is responsible for global warming–if so, to what extent;
- list the greenhouse gases emitted by agricultural practices and discuss how they are influencing the climate;
- suggest practices/ measures which can mitigate these greenhouse gases;
- suggest some measures on policy level to reduce the negative impact of agriculture on environment; and
- describe the positive and negative impact of agriculture on environment.

3.2 IMPACT ON NATURAL RESOURCES

Nations in all regions of the world, if they are to provide for long-term well-being of their citizens, must find the right means to protect the environment to ensure continued access to natural resources, generation to generation.

Deterioration of natural resources is being caused by various factors. Inappropriate agricultural development is one such factor. Conventional agricultural practices result in land degradation, deforestation, pollution of water bodies and loss of biodiversity. Some hot spots of severe environmental deterioration may be cited:

- the river basins of the Indus, Tigris and Euphrates in the middle east Asia (salinization),
- the foothills of Himalayas (water erosion),
- the forest margins of the lower Amazon (overgrazing and nutrient loss),
- the peri-urban areas of Mexico City (pollution from agricultural chemicals),
- the humid low land areas of Africa (nutrient depletion, acidification and erosion),
- the sub-humid, semi-arid border zone of West Africa (migration from dry land degradation), and
- the North-western plains of India (crisis due to ground water depletion).

In this section we will examine the negative impact of agriculture on environment.

3.2.1 Pollution

High production levels in modern agriculture are achieved by using nutrients such as nitrogen (N), phosphorus (P) and potassium (K) in the form of chemical fertilizers, manures, sludge, legumes and crop residues. When nutrients are applied in excess of plant needs they have the potential to pollute soils, and surface and ground water. A significant portion of nitrogenous fertilizers leaches through the ground and increases the nitrate concentration of ground water. When this high nitrate concentration water is used for drinking, it may cause diseases like methaemoglobinaemia (blue baby) in bottle fed babies and also cancer. WHO has prescribed the safe drinking water limit for nitrogen (N) as 45 ppm (part per million). But the study of nitrate content of ground water in several parts of India has revealed that in water table aquifers (dug wells), the nitrate concentration at many places is quite high, more than 100 ppm. (mg/l). Table3.1 shows the worst affected areas in India having nitrate concentration more than 300 ppm.

Table 3.1: Nitrate concentration in various Indian states exceeding 300 ppm

State	Site	District	Nitrate Concentration (ppm)
West Bengal	Jangipur	Murshidabad	480
Uttar Pradesh	Birdha	Hamirpur	434
Uttar Pradesh	Bansi	Jhansi	558
	Badshapur	Jaunpur	300
	Hastinapur	Meerut	694
	Mirapur	Saharanpur	300
	Bangarmaou	Unnao	390
Punjab		Sangrur	362
		Bhatinda	567
		Hoshiarpur	435
Haryana		Ambala	990
		Faridabad-1	560
		Faridabad-2	430
		Sirsa	325
		Hissar	419
		Hisar-2	363
		Hisar-3	610
		Gurgaon-1	310
		Gurgaon-2	450
		Gurgaon-3	722
		Mahendragarh-1	1310
		Mahendragarh-2	300
		Mahendragarh-3	393
		Mahendragarh-4	385
		Mahendragarh-5	830
Jammu & Kashmir		NIL	
Himachal		NIL	
Orissa	Bisam	Koraput	310
Bihar		NIL	

Though the nitrate in water is harmful for drinking purposes, it is beneficial for crops. Most of the plants/crops take nitrogen in the form of nitrate or ammonium. When this water having high nitrate concentration is used for agriculture, the requirement of nitrogen fertilizer is reduced accordingly. For example, 10 cm irrigation with ground water containing 100 ppm nitrate (mg/l) will contribute 44.5 kg of NO_3-N. If a farmer is using the recommended dose of 120 kg N, then three irrigation of such water will meet the entire nitrogen requirement of the crop thus making any additional nitrogen unnecessary.

In crop production the main emphasis is on the use of synthetic N fertilizers. As an example, in Haryana N, P (P_2O_5), K (K_2O) is used in the ratio of 48:11:1 showing the heavy dose of nitrogen application as compared to P and K. If the NO_3 concentration in ground water is not taken into consideration and additional nitrogen is applied, it will further accentuate the nutrient imbalance and ground water pollution may go on accumulating further. Excessive nitrogen is also not good for plants because it affects the maturity of crop adversely. It may cause lodging and even reduce the sugar content in beetroot and sugarcane crops.

Besides giving the required elements to the crop, the chemical fertilizers used in agriculture also supply heavy metals to the soils. Though some of them like copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) in low concentrations are beneficial to the crops as micronutrients, some of the other heavy metals like cadmium, lead, arsenic are toxic and may pollute the soils resulting in uptake of these toxic heavy metal by plants and enter the food chain for humans and animals. It is therefore, necessary to know about such fertilizers, which contribute more heavy metals thereby, exceeding the safe limits.

Table 3.2: Heavy metal contents (ppm) of some of the fertilizers

Fertilizer	Cu	Zn	Mn	Mo	Pb	Cd
Single super phosphate	26	60-165	65-270	3.5	609	187
Urea	0.36	0.5	0.5	0.2	4	1
Calcium Am. Nitrate	0.2	6	11	-	200	6
Muriate of Potash	3	3	8	0.2	88	14

Rock Phosphate is also responsible for heavy metal pollution.

Impact on air pollution

Though agriculture is not polluting the atmosphere directly, there are incidences when air pollution occurs and becomes responsible for human health hazards. It is mainly during the accidents and gas leaks in factories where pesticides are manufactured. You would recall that a major accident that occurred in December 1984 when a poisonous gas called Methyl Isocyanide leaked from the Union Carbide factory in Bhopal, India, causing hundreds of deaths and injuring and disabling many others. Many cases of illness have been reported from Karnataka and Kerala during pesticide spraying in the cashew nut plantations (Down to Earth, 2001).

Gaseous emissions from fertilizer manufacturing units are also responsible for air pollution. (Emission of greenhouse gases from agriculture is discussed later in this unit).

SAQ 1

a) How does agriculture lead to nitrate pollution of ground water?

b) What should be done to prevent further nitrate pollution?

3.2.2 Land Degradation

In terms of direct impact on the environment, farming activities are major contributors to soil erosion, land salinization and loss of nutrients. For example, it has been estimated that about 25 percent of soil degradation in Asia and Pacific region has occurred directly from agricultural activities.

One of the most serious impact of intensive agriculture is the clearing of forest land and burning of vegetation. In fact agriculture is the most important cause of forest loss in Southeast Asia. Subsequent burning of the remaining vegetation after land clearing had been responsible for the haze that covered much of South-east Asia in 1997 and 1998. The burning of vegetation in Kalimantan and Sumatra, after land clearing for oil palm plantations, got out of hand and spread to forest areas that were not supposed to be burnt. The problem became more serious when the peat just below the soil surface also started burning. Once the peat land catches fire it is very difficult to extinguish it. The smoke produced mainly contributed to the haze experienced in South-east Asia during last two years.

Decline in Soil Nutrients and Soil Biological Activity

Soil fertility and soil health are two major attributes of soil. Intensive agriculture without proper care is responsible for depletion of soil nutrients. A fertile soil has all major and micro and secondary nutrients, which are needed by crops. Once you grow a crop with excessive fertilizers (say nitrogenous) the crop also draws many other nutrients, which are not supplied, by these fertilizers. A crop may draw zinc, sulphur or any other element and the soil may become depleted in that.

Soil biological activity is another important attribute of the soil. By indiscriminate use of fertilizers and pesticides, soil microbial activity is affected. Even earthworms and other soil organisms are affected by intensive agricultural practices.

Decline in Soil Structure

Take the example of bricks. If the bricks are just kept haphazardly one over the other, it will form an unstable heap. But if the same bricks are arranged properly and mutually bounded, they can form a house or factory. In the same manner soil can be a loose and unstable assemblage of random particles or it can be a properly structured pattern of inter-bonded particles associated into bigger aggregates having regular sizes and shapes. The manner in which the soil particles are packed and held together in a continuous spatial network is commonly called soil matrix or fabric. The arrangement and organization of the particles in the soil is called soil structure.

Soil structure is strongly affected by changes in climate, biological activity and soil management practices. It is vulnerable to destructive forces of mechanical and physico-chemical nature. Soil structure also affects the retention and transmission of fluids in soil, including infiltration and aeration.

Agricultural practices responsible for decline in soil structure are

- Excessive cultivation/ tillage;
- Overgrazing and loss of soil cover;
- Excessive Animal / machine movement on wet soils (Fig. 3.1).

(a)

(b)

Fig.3.1: Some of the agricultural practices responsible for declining soil structure: a) Excessive movement of heavy machines; and b) Overgrazing

Whenever soil is disturbed it becomes loose and may move with water or wind. There is natural erosion of soils, especially in hilly areas. But there too human activity/agricultural activity enhances soil erosion. Levelling of the land and the drainage system also cause environmental problems.

Soil erosion in humid tropics is a very serious problem especially on slopes. Poor cultivation techniques, overgrazing, lack of vegetative cover are agricultural practices that lead to soil erosion.

Much of the eroded soil ends up in waterways. Downstream sedimentation is a serious impact of modern agricultural practices. Sedimentation fills in productive water reservoirs, destroys fisheries, coral reefs in tropical waters and as we had said earlier sediments carry ammonia, nitrates, and other chemicals in downstream waters causing eutrophication.

Soil Salinization

The soil or water containing excessive salts is classified as saline. The degree of salinity is measured by the concentration of salts. The easiest way to quantify the concentration of salts in a soil is to measure its electrical conductivity (EC). Its unit is Siemens/m. Soil with less salt will have low electrical conductivity. As the amount of salts increases its EC also increases. A soil is classified as saline if its EC becomes more than 4 dS/m. A number of factors are responsible for salinity build-up. Some of them are nature and content of soluble salts in irrigation water, soil type, water table, nature of crops grown, and the water management practices.

The agricultural practices responsible for saline soil problems are:

- Excessive drawing of ground water
- Water logging
- Use of improper fertilizers/pesticides
- Too frequent irrigation
- Use of brackish water for irrigation.

Canal Water Irrigation

Expansion of irrigation has been one of the key strategies in achieving self-sufficiency in food production in the region. For example, India has increased net irrigated area from 20 M ha in 1950 to about 45 M ha in 1995. A major expansion in the irrigated area has been achieved through transported canal irrigation. In almost all such cases the ground water table, which was several meters deep prior to introduction of irrigation canals, has risen. When ground water table reaches within 2 m of the surface, the ground water table contributes significantly to evaporation from soil surface and causes soil salinization. In most canal-irrigated areas, soil deterioration due to accumulation of salts has assumed a serious dimension. According to one estimate about 50% of the canal-irrigated areas are affected by salinity.

Ground Water Irrigation

Salt problems have also increased where saline ground waters have been used for irrigation in the absence of good quality irrigation water. Ground waters are being exploited to supplement the water requirement for producing more food, fodder and fibre. In India about 40% of the net irrigated area receives irrigation through ground waters drawn through wells. A large number of ground water aquifers especially in the states of Rajasthan, Haryana and Uttar Pradesh are unfit for irrigation as their use leads to salinity.

In coastal areas, excessive exploitation of ground water for agriculture has caused intrusion of sea water, resulting in worsening of salinity related problems.

Soil acidification

When pH of a soil becomes less than 6.5 it becomes acidic. Normally soils having pH between 6.5 and 7.5 are classified as neutral soils. If the soil pH becomes lower than 6.5 it becomes acidic and if it becomes higher than 7.5 it is classified as alkaline.

Agricultural practices that may cause soil acidification are:

- Excessive use of acidifying fertilizers.
- Use of shallow rooting pastures.

SAQ 2

What is soil structure and what agricultural practices disturb it?

3.2.3 Water Resources

The growth of agriculture and urbanization has imposed growing pressure on the South Asian region's already strained water resources in terms of both quality as well as quantity. This is evident in the gradual decline in per capita availability of water throughout the region. In India, for instance, the per capita availability fell from 6000 cubic meters in 1947 to 2300 cubic meters in 1998. Estimates for the year 2030 predict acute shortage of water in India (TERI 2000). Use of groundwater for irrigation has led to the depletion of underground aquifers in several parts of the region.

In some parts of the Indian states of Haryana, Rajasthan, Punjab and Gujarat the extent of over exploitation ranges from 100%-260% as compared to the critical levels of 85%. In Bangladesh excessive withdrawal of water has led to water logging and salinity and to land subsistence in cities like Dhaka (TERI 2000).
Water quality is affected through intensive agriculture in the following ways:

- Soil salinity due to water logging in irrigated areas;
- Soil salinity due to water logging in dry land;
- Contamination of ground water by nitrogen through nitrate;
- Eutrification of rivers, marshes and lakes; and
- Contamination of water by agrochemicals.

Lowering of Water Table

Due to excessive withdrawal of water for irrigation, the ground water table is lowered. In some cases it has gone down at the rate of 2-3 meters per year.

The methods of irrigation presently used are not very scientific. With a lot of gadgets now available for measuring the status of water/ moisture in the soil or when the crop requires water, we can make judicious use of water and save a significant quantity of water. Standing water throughout the rice crop is not essential. There are better methods of irrigation like drip irrigation and sprinkler irrigation to save water (Fig.3.2). These methods have several advantages over conventional methods of irrigation.

It is worth mentioning how a water scarce country like Israel has solved this problem by modern methods of irrigation, timely application of water, recycling of water etc.

(a)

(b)

Fig.3.2: a) Drip irrigation; and b) sprinkler irrigation is more useful for saving water

"India has on the whole good rainfall and reasonable water resources. We can manage with water available provided we follow Gandhi's advice- Nature provides for every body's need but not for everybody's greed." ***(Quoted from DR. M.S. Swaminathan's article on Greening a Nation published in Times Agricultural Journal Nov-Dec, 2001)***

SAQ 3

How can we save water and still fulfil the requirements of the crops?

3.2.4 Biodiversity Erosion

Within the Asia-Pacific region, overall habitat losses have been the most acute in the Indian Subcontinent. The underlying causes are international trade in timber; introduction of non-native species, improper use of agro-chemicals, excessive hunting and poaching (TERI 2000).

Intensive agriculture has resulted in loss of biodiversity in the following ways:

- Pressure on habitat of wild organisms;
- Loss of species when the habitats are degraded;
- Abandoning of traditional varieties in favour of high yielding varieties; and
- Practice of monoculture for more production of a particular variety (Pusa basmati in rice). This is normally done either because of high yields or some varieties which are more in demand. You will learn more about biodiversity erosion in Unit 8 of the next block of this course.

3.2.5 Pesticide Residues

Pests are undesirable competitors, parasites, or predators.

All types of agriculture suffer from pest infestation. Even today with modern technology the total losses from all pests are huge. The major agricultural pests are insects, diseases and nematodes, and weeds and vertebrates (mainly rodents and birds) that feed on grain and fruits.

Before the Industrial Revolution, farmers could do little to prevent pests except remove them when they appeared or use farming methods that tended to decrease their density.

With the advances in modern agricultural sciences, chemical pesticides were developed. The use of pesticides has grown, reaching $31.25 billion worldwide in 1996. About 80% of the pesticides in use are applied in developing countries.

Pesticides are a group of chemicals meant for preventing/ destroying any pest detrimental to man or his interest during production, processing, storage, transportation and distribution of food items like cereals, fruits, vegetables and other crops. These include insecticides, herbicides, rodenticides, nematicides, chemosterilents, mollusides, fungicides, plant growth regulators, defoliants, desiccants attractants, and repellents.

Box 3.1: Chemical pesticides

Chemical pesticides like DDT, aldrin and carbendazim etc. have created a revolution in agriculture. However, in addition to the negative environmental effects of individual chemicals such as DDT, their use has other major drawbacks. One such problem is known as *secondary pest outbreaks*, which occur after extended use (and possibly because of extended use) of a pesticide. Secondary pest outbreaks can come about in two ways: (1) reduction in one target species reduces competition with a second, which then increases and becomes a pest or (2) the pest develops resistance to the pesticides through evolution and natural selection, which favour those in the population with a greater immunity to the chemical. Developed resistance has occurred with many pesticides.

It has been estimated that the crop losses in India because of pests and diseases vary from 10% to 30 % depending upon the crop, climate and region. In financial terms these losses amount to Rs. 290 billions per year (Table 3.3).

Table 3.3: Estimated crop losses due to pests and diseases in India

Crop	Loss in %	Financial loss in million Rs.
Rice	18.6	55, 120
Wheat	11.4	14,150
Jowar	10.0	1,732
Pulses	7,0	4,840
Oilseeds	25.0	41,800
Cotton	22.0	20,000
Sugarcane	15.0	13,360

Monitoring of Pesticide Residues

All India Coordinated project on Pesticide Residues conducted analysis of 4100 fruits and vegetable samples collected from different states of India. Out of these 2265(55%) samples were found contaminated with pesticides. However, only 9% of them exceeded the MRL (Maximum Residue Limit) as you can see from Table 3.4.

Table 3.4: Region wise contamination of fruits and vegetables by pesticides

State/Centre	No of samples analysed	% samples contaminated	% samples above MRL
Haryana	1236	56.2	4.5
H.P.	436	19.5	1.4
Tamil Nadu	85	91.8	15.3
Gujarat	104	80.8	13.5
A.P.	275	29.8	-
U.P.	244	100	45.9
W.B.	75	56	-
Kerala	72	100	52.8
Punjab	148	58.1	4.7
Orissa	105	51.4	12.4
Delhi	68	77.9	-
Assam	32	46.9	-
Rajasthan	388	53.4	12.1
Karnataka	370	19.7	7.3
M.P.	195	96.5	1.5
Maharashtra	278	73.4	13.7
Total Average	**4111**	**55.1**	**9.5**

The analysis has shown that pesticide residues affect most of the crops. A comparative analysis is given in Table 3.5.

Table 3.5: Contamination of fruits and vegetables crops by pesticides (crop wise)

Crop	No of samples	% of samples contaminated	% samples above MRL
Tomato	598	45.3	5.4
Cucumber	186	52.5	6.5
Apple	142	18.3	--
Okra	468	60.0	15.8
Cabbage	302	62.6	7.0
Smooth Gourd	81	64.2	--
Pointed Gourd	15	46.7	--
Brinjal	843	58.5	9.8
Capsicum	124	31.5	12.1
Indian Bean	22	72.7	9.1
Bitter Gourd	125	65.6	6.4
Ridge Gourd	46	47.8	--
Pea grains	161	47.8	7.5
Potato	219	62.6	9.6
Cauliflower	376	66.2	16.8
Pea	20	65.0	--
Beans	8	62.5	--
Spinach	40	85.0	7.5
Mustard	12	41.7	--
Cowpea	55	81.8	32.7
Cluster bean	24	50.0	4,2
French bean	51	17.6	15.7
Bottle Gourd	33	45.6	3.0
Snake Gourd	36	80.5	19.4
Carrot	14	57.1	--
Fenugreek	12	41.7	8.3
Pigeon pea	12	100	58.3
Total Average	**4111**	**55.1**	**9.5**

Pesticides residues were also found in milk samples collected from the following locations showing that the cows and buffalo were eating such fodder or feed material which contained pesticide residues and then these residues entered in the food chain of milch cattle and in the milk (Table 3.6).

Table 3.6: Residues of HCH and DDT in whole milk in India

(a) HCH (Hexachloro cyclohexane)

Location	No. Analyzed	No. contaminated	No. above MRL
New Delhi	12	12	7
Ludhiana	30	30	30
Hissar	25	25	25
Kanpur	24	24	24
Hyderabad	38	38	38
Coimbatore	90	90	60
Pusa Bihar	24	8	8
Bangalore	30	25	25
Bhubaneshwar	45	45	45
Jorhat	12	12	12
Jaipur	20	20	17
Anand	60	60	59
Vellyani	25	25	12

MRL in dairy milk HCH = 0.01 mg/kg

(b) DDT (Dichloro diphenyle trichloro ethane)

Location	No. Analyzed	No. contaminated	No. above MRL
New Delhi	12	12	12
Ludhiana	30	30	25
Hissar	25	25	02
Kanpur	24	19	09
Hyderabad	21	21	3
Coimbatore	80	80	22
Pusa Bihar	24	11	9
Bangalore	30	26	02
Bhubaneshwar	45	36	11
Jorhat	31	31	22
Jaipur	16	16	10
Anand	60	60	52
Vellyani	18	18	10

MRL for dairy milk DDT = 0.05 mg/kg

Pesticide Residues in Fish

The data on pesticide residue in fish suggests that fish in India are relatively less contaminated. Out of 82 samples analyzed, only 40% were found contaminated with residues of insecticides and none of the samples was above MRL. These samples were collected from Kerala, Assam and Andhra Pradesh and residue analysis was conducted for HCH, DDT, Endosulphan, monocrotophos and quinaphos.

Pesticide Residues in Poultry and Poultry Feed

Chicken and eggs are the preferred food in a non-vegetarian diet. In India samples of eggs and chicken were analyzed for the residues of HCH, DDT, aldrin and carbendazim (a fungicide). The analysis of chicken flesh have shown that residues of DDT, HCH and aldrin, were either non-detectable or below MRL. But surprisingly residues of carbendazim fungicide used to control fungal diseases were much higher than its MRL value. The presence of high amounts of carbendazim in poultry feed clearly shows that these are coming from feed particularly maize as maize grains are treated to control fungal diseases.

The area under pesticide cover has increased from 6 Mha in 1960 to 125 Mha in 1990. At present there are about 145 pesticides in use and annual consumption is about 85000 t. The consumption of pesticides in India is the maximum among the South Asian countries. During the last five decades this has increased by about 500 times, i.e., from 154 t in 1953 to 85,000 t in 1998.India is also the largest producer of pesticides in South Asia, with more than 500 industries producing it.

Notwithstanding this fact, the consumption of pesticides in India is quite low (about 0.5 kg /ha) as compared to countries like Korea and Japan where its consumption rate is 6.6 and 12.0 kg/ha, respectively. There is widespread contamination of food commodities with pesticide residues. In a recent survey by ICMR (Indian Council of Medical Research) it was revealed that 51% of our food items were contaminated with pesticides out of which 20 % had pesticides residues above MRL (Maximum Residue Limit). In spite of the warnings and bans the use of pesticides in India is increasing at the rate of 2-5 % per year and is likely to grow in future as well unless strict measures are taken. On a regional level, agricultural run-off has also contributed to ocean pollution. An estimated 1800 t of pesticides enter the Bay of Bengal annually and increased use of pesticides in some areas has resulted in contamination of molluscs and fish species.

Shrimp breeding in coastal swamps has accelerated the depletion of mangroves in estuaries, lagoons and bays and threatens such important natural processes as soil binding, nutrients recycling and prevention of soil erosion and silt accumulation.

SAQ 4

Why are pesticides used in agriculture? Find out the MRL of pesticide residue in your area.

3.3 IMPACT ON CLIMATE CHANGE

So far we have discussed the local and regional effects of agriculture on the environment. Global effects are not so obvious, though they are equally serious. In this section, we will examine and assess the global impact of modern agriculture on climate change. Intensification of agriculture has resulted in heavy reliance on irrigation, increased fertilizer and pesticides use and crop residue burning. All of them have a direct impact on global climate change via emission of greenhouse gases.

3.3.1 Greenhouse Gas Emissions

Green house effect is the warming of the lower atmosphere and surface of a planet by a complex process involving sunlight, gases and particles in the atmosphere.
All hot objects emit electromagnetic radiation at a range of wavelengths depending on the temperature of the object. The higher the temperature is, the shorter the wavelength of the radiation, and vice versa. The sun, with a surface temperature of over 6000^{o}C, emits radiation with wavelengths 200nm to 4μm.

The earth is enveloped by gaseous atmosphere and gases in the atmosphere absorb radiation selectively. When the short-wave radiation from the sun passes through these gases, they allow it to fall on the earth. As a result, the earth absorbs some of the radiation and it gets heated to a mean temperature of about 15^{o}C. In turn, the earth radiates long wave infrared radiation some of which is absorbed by the atmospheric gases and particles. As a result the gases and particles are heated. Sending out infrared rays of their own then cools them. Some of these rays go into space. The remainder radiate back towards the earth's surface adding to the warming of the surface layer of air (Fig. 3.3). The heat trapping gases of the atmosphere are known as **greenhouse gases.**

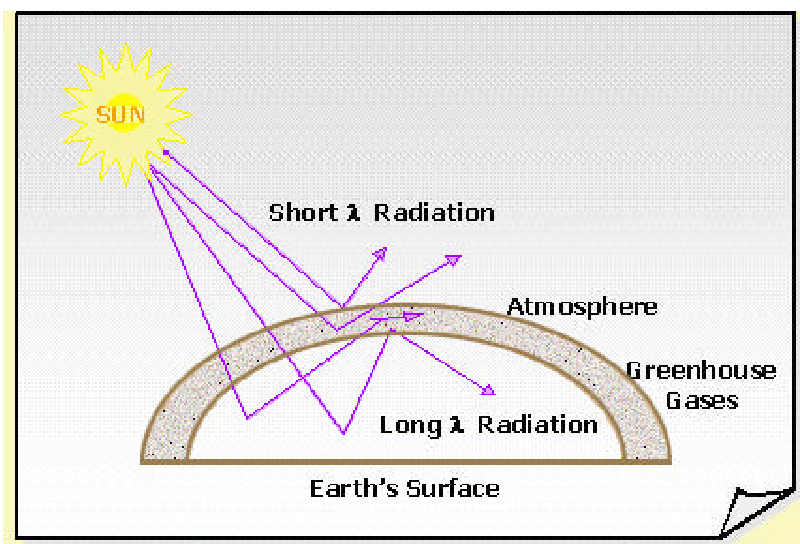

Fig.3.3: Greenhouse effect; λ refers to the wavelength of the radiation. Short λ implies greater energy and long λ radiation has less energy

The greenhouse gases are: carbon dioxide, methane, water vapour, nitrous oxide and ozone. The natural greenhouse gases keep the earth roughly 33°C warmer than what it would be if there was no atmosphere. However, on an average for the earth as a whole, the incoming solar energy is balanced by outgoing terrestrial radiation. It is important to understand that the green house effect is a natural phenomenon that has been occurring for millions of years on earth as well as other planets of our solar system. The majority of natural greenhouse warming is due to water in the atmosphere but the gases we are concerned with are those that result in part from anthropogenic processes, that is, those that occur due to human activities.

Increases in the concentration of greenhouse gases will reduce the efficiency with which earth cools. More of the outgoing terrestrial radiation from the surface is absorbed by the atmosphere and emitted at higher altitudes and colder temperatures. This results in an **enhanced greenhouse effect** which tends to warm the lower atmosphere and surface. This effect has operated in the earth's atmosphere for billions of years due to the naturally occurring greenhouse gases: water vapour, carbon dioxide, ozone, methane and nitrous oxide.

Anthropogenic aerosols (small particles) in the troposphere, derived mainly from the emission of sulphur dioxide from fossil fuel or biomass burning can absorb and reflect solar radiation. They create a negative effect and cool the climate. But these aerosols have a much shorter lifetime (days to weeks) as compared to most greenhouse gases (decades to centuries) so their presence responds much more quickly but for short duration.

Any change in the radiative balance of the earth whether due to greenhouse gases or aerosols will tend to alter atmospheric and oceanic temperatures and the associated weather patterns (hydrological cycles, cloud distribution and rainfall patterns).
As explained above, the presence of these green house gases has raised the earth's surface temperature from –19° C to 15° C.

It is quite clear that not only the presence of these gases but their contribution in raising the temperature is also equally important. Some gases contribute more and some less depending upon their concentration and warming potential (Table 3.7).

Table 3.7: Greenhouse gases influences by anthropogenic activities

Gas	CO_2	CH_4	N_2O	CFC-12
Pre-industrial atmospheric concentration	280 ppmv	0.70 ppmv	280 PPBV	0
Current concentration	370 ppmv	1.72 ppmv	310 ppbv	5.03 pptv
Current annual increase (%)	0.5% (1.5 to1.8 ppmv)	0.8% (0.013 ppmv)	0.25% (0.75 ppbv)	4% (18-20 pptv)
Atmospheric life time (Yrs)	50-200	12-17	150	102
Global warming potential relative toCO_2	1	24.5	320	4000

The table shows that from many thousand years to about 200 years ago the concentration of these green house gases in the atmosphere was almost the same/ unchanged. The changing trend started only 200 years ago mainly because of increased anthropogenic activities. Not only this, some of the gases (CFCs) which were not present in the atmosphere earlier entered into atmosphere from the year 1930 onwards. Though their concentration is very low, their overall contribution to global warming is very high.

The rise in the concentrations of greenhouse gases in the atmosphere is caused primarily because of human and industrial activities. The increasing levels of CO_2, the most important greenhouse gas, are mostly because of fossil fuel combustion. Similarly, CFC emissions are only caused due to industrial processes and products. On the other hand the increased agricultural activities and organic waste management are contributing to the build-up of methane and nitrous oxide (Fig. 3.4).

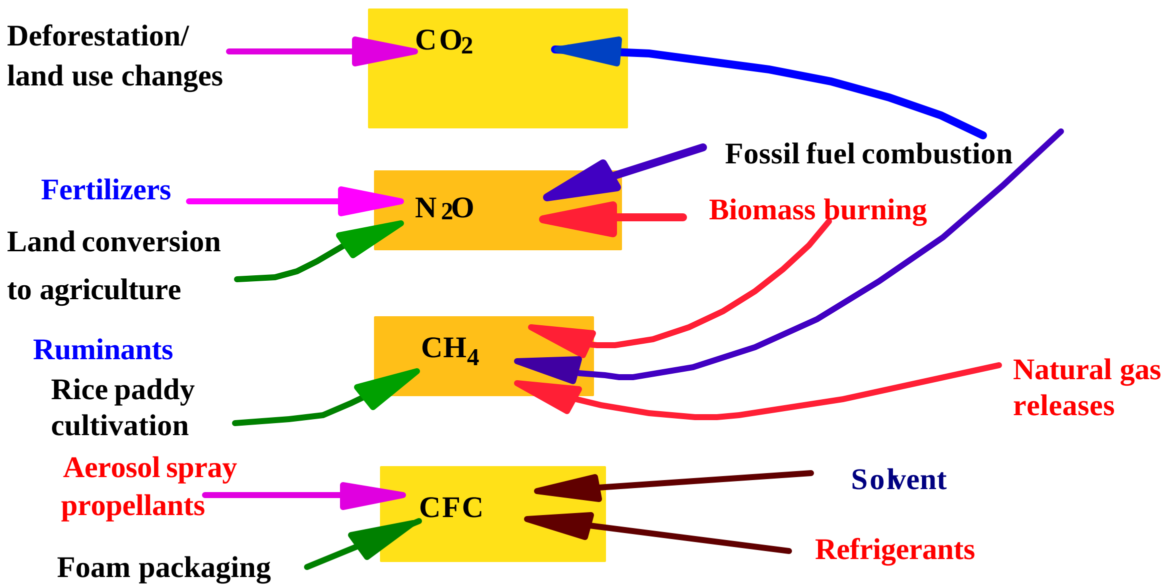

Fig. 3.4: Greenhouse Gases and their anthropogenic sources

The composition of greenhouse gases is shown in Fig. 3.5. Note that carbon dioxide, methane and nitrous oxide are directly related with agriculture.

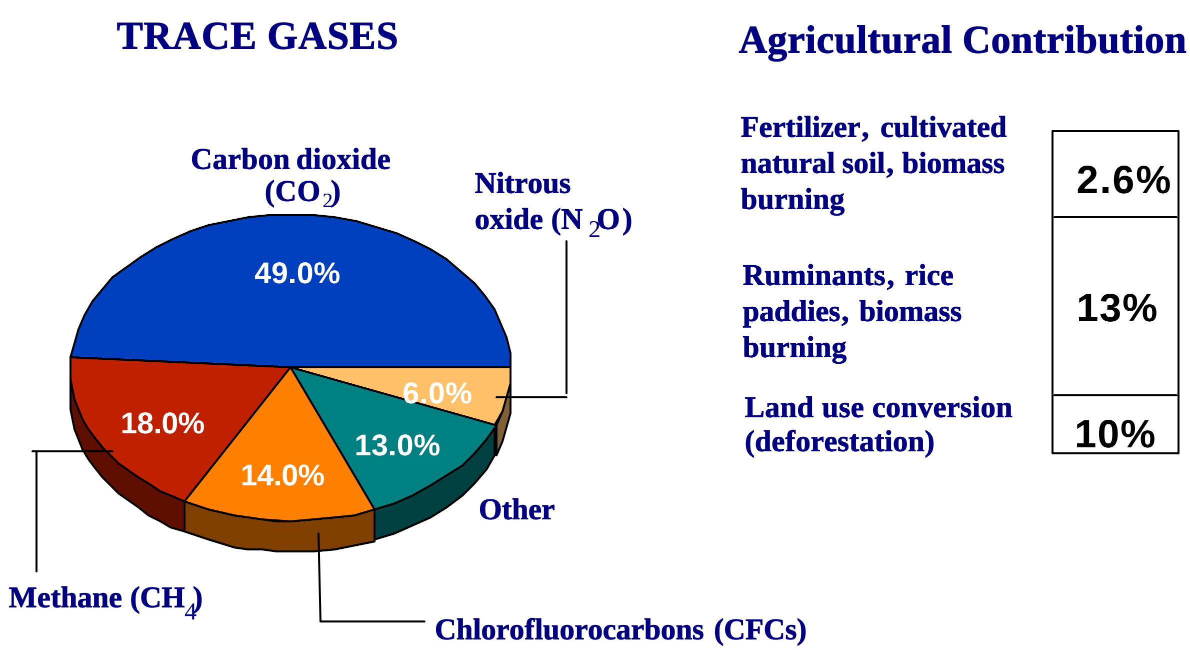

Fig.3.5: Composition and source of greenhouse gases in the atmosphere

While it is certain that agriculture is a source of carbon dioxide, methane and nitrous oxide, it can also be considered as a sink of carbon dioxide and to some extent methane. We will discuss each gas separately in the following subsection.

SAQ 5

a) Why does the sun radiate in the short wave range (mainly UV and visible) while the earth radiates long wave radiation?

b) Why is global warming known as greenhouse effect?

3.3.2 Carbon Dioxide

Agriculture is not a major source of carbon dioxide. It mainly comes from the burning of fossil fuels for energy (electrical power, vehicles etc). However, agriculture and forestry play an important role in land use conversion, (land clearing and forest burning for cultivation or grazing) which is the second largest cause of increased carbon dioxide emission. The net effect is carbon loss from both biomass and soils. Main source of carbon dioxide to the atmosphere by agriculture is through tillage. The tillage operation increases the biological decomposition of soil organic matter resulting in release of CO_2. The second pathway is use of machinery where fuel (diesel) releases CO_2. The third important source of CO_2 is burning of crop residue.

Inter Government Panel on Climatic Change (IPCC)

It may be noted the agriculture is also a sink for CO_2. During plant growth, the process of photosynthesis absorbs atmospheric CO_2. Due to this very reason the global Climate Change Community does not consider agriculture as a source of CO_2. (In official GHG (Greenhouse Gases) accounting procedures as supported by IPCC).

Carbon dioxide from Tillage Operations

During a tillage operation, soil aggregates are broken, increasing oxygen supply and surface exposure to soil organic matter and thereby promote its decomposition.

International Maize and Wheat Improvement Centre (CIMMYT)

In one long- term trial at CIMMYT, Mexico, the impact of 3-4 cultivations per year was compared with a no tillage experiment. After 8 years it was revealed that soil organic carbon in the top 20 cm declined from 1.37% to 1.12 %. The net loss of soil organic carbon in 8 years was 3.6 t C/ha (equivalent to 450 kg C/ha/yr.).

Where has this carbon gone? It has gone to the atmosphere through CO_2 emission.

Fuel Consumption in Agriculture

Heavy diesel fuel used by tractors is also responsible for CO_2 emission. It is estimated that for every litre of diesel consumed, 2.6 kg of CO_2 is released to the atmosphere. Assuming that 150 litres of diesel is used per hectare for tractor and irrigation pumping in conventional systems, this would amount to 400 kg CO_2 being emitted per year. An off site source which is often neglected, is the production of CO_2 during the manufacture of fertilizers. It is estimated that production of I kg of N fertilizer would release 1.8 kg of CO_2.

3.3.3 Methane

Methane is the lightest hydrocarbon having one carbon and four hydrogen atoms. Its molecular weight is 16. It is also a fuel gas commonly called marsh gas because it is produced from marshy lands. Biogas or Gobar gas also contains 60-70% of methane.

Even if the concentration of methane is quite low as compared to that of CO_2, its global warming potential (GWP) is 20 times that of CO_2. Rice and ruminant animal production are the two largest sources of anthropogenic methane. These two sources together contribute about 40% to global methane budget (Table 3.8).

1 Tg = 1 million tons

Table 3.8: Estimated sources and sinks of methane in Tg/ yr (IPCC 1995)

Sources	Individual estimate	Total
Natural		
Wetlands	115(55-150)	
Termites	20(10-50)	
Oceans	10(5-50)	
Others	15(10-40)	
Total of Natural Sources		**160(110-210)**
Anthropogenic Sources		
Fossil fuel based		
Natural gas	40(25-50	
Coal mines	30(15-45)	
Petroleum Refining	15(5-30)	
Coal combustion	? (1-30)	
Total of fossil related		**100(70-120)**
Biogenic		
Enteric Fermentation	85(65-100)	
Rice paddies	60(20-100)	
Biomass Burning	40(20-80)	
Landfills	40(20-70)	
Animal wastes	25(20-30)	
Domestic sewage/waste	25(15-80)	
Total of Bionic Sources		275(200-350)
Total (All Identified Sources)		535(410-660)
Sinks		
Atmospheric removal		
Troposphere OH	445(360-530)	
Stratosphere	40(32-48)	
Soils	30(15-45)	
Total Sinks		515(430-600)
Implied Total Sources		**552(465-640)**
Implied Increase		**37(35-40)**

If domestic waste decomposition through sewage and landfills and burning of agricultural waste is also included under this category of anthropogenic sources of methane, its contribution may rise to about 70% (Fig. 3.6).

The methane we release today could still trap heat more than a decade from now. It stays in the atmosphere that long.
Each molecule of methane traps heat 20 times more effectively than a carbon dioxide molecule.

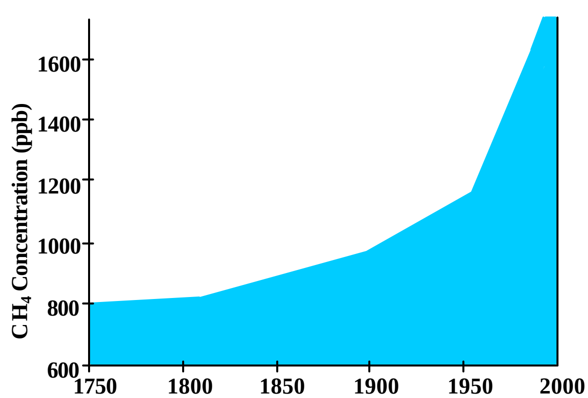

Fig.3.6: Methane on the rise. Since 1750 methane in the air has more than doubled due to human activity. It could double again by 2050.

Methane emission from rice fields

Methane is produced in soil during microbial decomposition of organic matter and reduction of CO_2 under strictly anaerobic conditions. The methane emissions are controlled by two microbial processes, i.e., CH_4 production through methanogenic bacteria and CH_4 oxidation through methanotrophs. While former requires strict anaerobic environment, the latter requires oxygen for metabolism. The dry terrestrial soils may also act as sink of atmospheric methane.

The continuously flooded rice fields are the source of methane, because anoxic conditions favour methanogenesis and production of methane and rice plants serve as conduit for its release to atmosphere. However, if the fields could be drained or intermittently irrigated, then the methane production as well as emission could be significantly reduced.

Global Methane Emission from Rice Fields

The global estimate of methane emission from rice fields started from 200 Tg/yr, which have come down to 60 (20-100) Tg/yr in 1996.There is a possibility of further decline in the estimated values of methane budget from rice fields. It is estimated that methane emission from rice fields is in the range of 25-54 Tg/yr.

Methane from Indian rice fields

Methane from Indian rice fields covering a harvested area of 42.3 Mha was estimated as 4-6 Tg/yr. There is no doubt that the continuously flooded fields emit considerable amount of methane, but the question would be the source of carbon substrate, which is needed for the methane production. This substrate comes from either the native organic carbon in the soil, or the applied organic carbon added to the soil in the form of organic manures, rice straw etc.

The rice plants also provide this carbon substrate in the form of organic leachates and root exudates. The recent measurements using both automatic and manual measuring system have clearly shown that methane emission is significantly reduced using the practice of intermittent irrigation as compared to continuous flooding.

The experiments in all parts of the world have shown that addition of organic manures like green manure, farm yard manure (FYM), biogas slurry, rice straw etc., enhances the methane emission from rice fields. The experiments conducted at IARI have also shown that methane emission from rice fields amended with biogas spent slurry is significantly lower than other organic amendments like green manuring, FYM etc.

Experiments have also shown that there is no significant increase in methane emission if neem coated urea is used in place of urea, while grain yields are significantly increased.

The total annual injection of methane into the atmosphere is estimated to be 552 (465-640) Tg and its oxidation being less, there is a net accumulation of about 37 Tg/yr. As a result, the abundance of methane in the atmosphere (which is currently 1.74 ppm) is increasing at a rate of about 0.7 % per year. Although the increase in annual load of methane in the atmosphere is only 1/100 that of CO_2, its high impaired absorption amounts to higher contribution (15-20%) in the global warming.

Role of organic wastes under continuously flooded rice fields

Organic wastes are the potential source of methane emission. Normally the wastes contain lot of water and the dry matter content of a large number of organic wastes is very low (10-20%). When these wastes are dumped, they remain in partially anaerobic conditions and produce both carbon dioxide as well as methane .The ratio of CO_2/CH_4

depends upon the toxic conditions of the dumps. When these wastes become a part of stagnant water, the amount of methane increases considerably. Among the various types of wastes, the most important is the animal excreta. But the crop wastes and other wastes which are also sometimes used in rice fields also emit methane. The more the organic matter in the stagnant water, the more methane is expected to come out. The process also depends upon the temperature and pH. Temperature between 30-35°C is most favourable for methane production.

The production of methane is reduced as the temperature goes down and below 15°C, the methane production becomes very low. As regards the pH, its range between 6.4-8.0 is most favourable, on either side of this range, methane production is reduced.

Box 3.2: Methane emission in South Asian Region

Under UNDP-IRRI Inter regional programme, methane emission from rice fields was measured at eight locations in five rice producing countries (India, China, Thailand, Philippines and Indonesia) covering main rice ecosystems, i.e., irrigated, rain fed and deepwater. The results revealed that irrigated rice fields had the highest emission rates of all rice ecosystems. Seasonal emission varied from $1g/m^2$ to $50\ g/m^2$.

Continuously flooded fields emitted more methane. Depending upon local precipitation, emission from rain fed rice fields may be less than half of the emission from irrigated fields and was generally less than $5\ g/m^2$. In a reference treatment at all these locations using common cultivar IR72 and continuously flooded conditions, the seasonal methane emission varied from $1.7\ g/m^2$ to $24.4\ g/m^2$, which may be attributed to soil conditions and climate.

Experiments at IARI during 1994-97 have shown that intermittent irrigation, which is the usual practice, reduces methane emission unto about 28%. At Pant Nagar the reduction in methane emission due to intermittent irrigation was found to be 30% as compared to continuous flooded conditions. IPCC in 1996, on the basis of results obtained by various rice growing countries, have suggested that emission factors under single and multiple aeration as 0.5 and 0.2 of that against continuously flooded fields. Using IPCC methodology and country's default value of 10 g/m2, the methane emission from rice cultivation in India should not exceed 2.5Tg/yr.

The main reason of low methane emission from rice fields in India is that the soils of major portion of rice growing areas have very low organic carbon. Incubation studies on some soils of rice growing areas of India have shown large differences in the methane production potential because of their organic carbon content. The use of organic manuring is also not very common in India and Indian soils have very low organic carbon. This is one of the reasons of low methane emission from Indian rice fields.

Methane Emission from Burning of Crop Residues

The burning of crop residues also contributes to global methane budget. For each ton of residues that is burnt 2.3 kg of methane is released which is equivalent to 48.3 kg of carbon dioxide.

In order to clear the field for the next crop, farmers quite often burn the crop residue, because that appears to them as the easiest way.

As an example take the case of rice-wheat system in Indo-Gangetic plains. Assuming about 10 t/ha of residue production and if half of the 12 million ha area under rice-wheat is burnt, a total of 0.14 million tons of methane is emitted. This is equivalent to 20% of the total methane emitted from rice fields in this area. Hence burning of crop residues is also an important source of methane besides carbon dioxide.

Mitigation of methane emission from rice fields

Experiments have shown that methane emission can be reduced significantly (Table 3.9) by adopting the following mitigation practices:

- Water management: through intermittent irrigation or drainage;
- Use of digested manure instead of fresh manure; and
- Selection of suitable cultivars which emit less methane.

But studies have also shown that mitigation of methane emission through intermittent flooding may lead to N_2O emission. However, more experiments are needed to quantify the combined effect of emissions of methane and nitrous oxide from rice fields. This has become necessary because the global warming potential of N_2O is 15 times more than that of CH_4.

Table 3.9: Estimated effect of management practices on CH_4 emission from flooded rice

Mitigation Practice	Estimated decrease Mt (CH_4)/yr
Irrigation management	5 (3.3-9.9)
Nutrient management	10 (2.5-15)
New cultivars and other practices	5 (2.5-10)
Total	**20(8-35)**

Methane Emission from Enteric Fermentation

Ruminants are the largest source since they are able to digest cellulose, a type of carbohydrate, in the presence of specific micro organisms in their digestive tracts. An adult cow emits about 200 litres of methane every day. The methane production from the digestive process of domesticated animals is a function of several variables including quantity and quality of feed intake, the growth rate of the animals, its productivity (reproduction and/ or lactation) and its mobility.

Feed Intake

Feed intake in terms of dry matter (DM) is most crucial for the estimation of methane emission from livestock and is generally expressed in terms of energy, i.e., MJ (Mega Joules) per kg dry matter. The total dry matter intake of an animal is converted to MJ as gross energy intake using the factor 18.45 MJ/kg.

The gross energy intake value (GE) for each animal category is arrived at, taking into account the Indian feeding conditions/ situations based on feed intake requirements of various categories of cattle. The requirement varies according to age, feeding situation, (stall or housed, pasture, grazing large areas) production level and performance (maintenance, lactation, work, breeding, growth etc).

Depending upon the population and the methane production potential of different livestock in India it is seen from Fig. 3.7 that cattle (cows) contribute maximum followed by the buffalo.

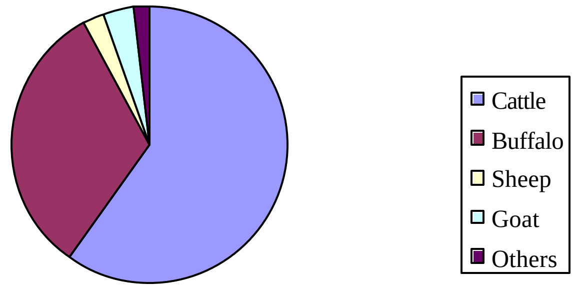

Fig.3.7: Methane Emission from Animal Sector in India.

Among the green house gases emitted from animal (enteric fermentation and manure management), methane was the highest (99.985%) with N_2O accounting for only very small fraction (0.015%), which is negligible. Methane emission from domestic animal source (anthropogenic activities) was 10.0 Tg for the year 1994 of which 8.9 Tg (90%) was from enteric fermentation and the balance 1.1 Tg (10%) came from manure management. The proportional contribution of emission is almost in the ratio of 9:1 (enteric fermentation and manure management).

The best way to mitigate the methane emission from enteric fermentation of ruminant animals is to improve their feed. Several efforts have been made to improve the feed in such a way that they produce less methane.

SAQ 6

a) Why is methane an important greenhouse gas even if its concentration in atmosphere is 1.8 ppmv as compared to a high concentration of about 360 ppmv of CO_2?

b) Can other aquatic plants and stagnant water emit methane?

3.3.4 Nitrous Oxide

Nitrous oxide is one of the oxides of nitrogen. Some other oxides of nitrogen like NO and NO_2 (together called NOx) are pollutants and are emitted by vehicles and other stationary engines. N_2O is another greenhouse gas responsible for climate change.

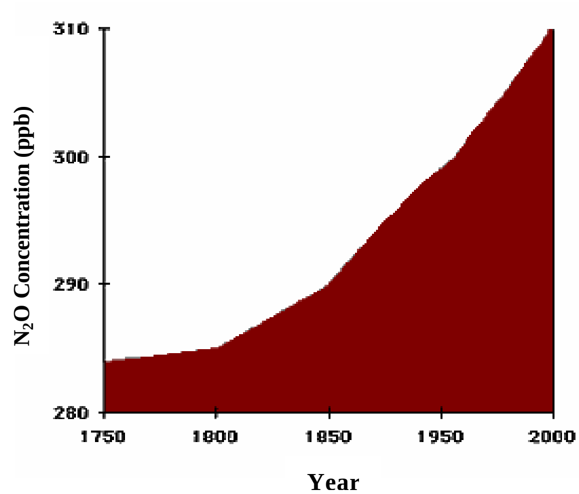

Fig.3.8: Nitrous oxide on the rise

Since 1750, nitrous oxide in the atmosphere has risen by more than 15 percent (see Fig. 3.8). Each year we add 7 to 13 million tons of nitrous oxide to the atmosphere mainly by using nitrogen-based fertilizers and disposing of human and animal wastes.

The nitrous oxide we release today could still trap heat more than a century from now. It stays in the atmosphere about that long. A nitrous oxide molecule traps heat about 200 times more effectively than a carbon dioxide molecule.

The Table 3.10 of the sources and sinks of nitrous oxide clearly indicates that there is a high degree of uncertainty in the emission figures of nitrous oxide. One of the reasons may be its low concentration in the atmosphere (300 ppbv) and determination of N_2O concentration at such low levels. But the latest measuring techniques have made it possible to measure these fluxes at reasonable costs. Hence it has become necessary to have more and more experimental measurements to come out with more and more reliable estimations.

Both fertilized and unfertilized soils emit N_2O. While the fertilizer is a source in case of fertilized soils, the inbuilt nitrogen of the soil contributes otherwise to the release of this gas. Measurement of N_2O fluxes from soils as a result of use of N in inorganic or organic forms is of great importance to the atmospheric scientists because of the effect of N_2O on ozone destruction and its radioactive forcing. But the soil scientists and agronomists are also concerned about the nitrogen losses from the applied fertilizers and manures.

Table 3.10: Sources/sinks of nitrous oxide

Sources	Production (Tg N/ yr)
Nitrification	?
Denitrification	?
Cultivated soils	1.8-5.3
Fertilized soils	<3
Unfertilized soils	4-5
Tropical soils	2.7-5.7
Temperate soils	0.6-4.0
Oceans	1-5
Fossil fuel	0.7-1.8
Biomass burning	0.2-1.0
Total	**17-20**
Total emission from soil	**5-15**
Sink	
Stratospheric reaction with ozone	6-11
Photolysis	11

Experiments have shown that both the processes of nitrification and denitrification contribute to the release of nitrous oxide from the soils.

Experiments in rice fields conducted at IARI have shown that as the redox potential becomes positive methane emission is decreased, but N_2O emission increases. In another experiment it has been shown that use of nitrification inhibitor DCD along with urea and ammonium sulphate reduces both the methane and nitrous oxide emission as compared to their lone use. Though there is lot of uncertainty about the amount of N_2O released, it is suspected that 1-2 % of applied N is lost as N_2O.

Nitrous oxide Emission from Histosols

The high organic soils undergo microbial process (both nitrific ation and denitrification) resulting in the release of nitrous oxide. It has been reported that these soils emit 2-15 kg /ha N_2O N /yr.

Indirect N_2O Emissions from Nitrogen used in Agriculture

The following pathways also contribute to nitrous oxide emissions because of inorganic and organic fertilizers applied in the fields.

1. Volatilization and subsequent deposition of NH_3 and NOx;
2. Nitrogen leaching and runoff;
3. Human and animal consumption of crops followed by further excreta/sewage;
4. Formation of N_2O in the atmosphere from NH_3; and
5. Food processing wastes.

N_2O Emissions from Animal Waste Management Systems

Nitrous oxide emission depends on the N_2 excreted by animals, its quantity, quality and its management. Animals themselves may be very small sources of N_2O but the proportion of total nitrogen intake that is excreted and partitioned between urine and faeces is dependent on the type of animal, the intake of dry matter, and the nitrogen concentration of the diet. Hence there are three potential sources of N_2O emissions related to animal production. These are (a) animals themselves, (b) animal wastes during storage and treatment, (c) dung and urine deposited by free-range grazing animals. N_2O emission emitted directly from animals is not reported here.

Production of N_2O during storage and treatment of animal wastes can occur via combined nitrification-denitrification of ammoniacal nitrogen contained in the wastes. The amount released depends on the system and duration of waste management. As fresh dung and slurry is highly anoxic and well buffered with near neutral pH, one would expect N_2O production to increase with increasing aeration. Aeration initiates the nitrification-denitrification reactions, and hence makes release of N_2O possible.

SAQ 7

What is the relative global warming potential of nitrous oxide?

3.4 SUMMARY

- Food, fibre and fodder are the three important produce of agriculture on which whole mankind is dependent. Even though the impact of agriculture practices on environment is quite significant, it is certain that only remedial measures can be adopted to reduce or prevent the negative impacts of agricultural practices on environment.

- Negative impacts of intensive and exploitive agriculture include water pollution, land degradation and associated problems of soils like soil salinization, soil acidity, soil acidity, depleting ground water reserves.

- Examples of pesticide residue in fruits, vegetables, milk, poultry products creating human and animal health problems are given.

- The emission of greenhouse gases from agriculture is a serious problem which is responsible for global warming and climate change. One of the important green house gases emitted by agriculture is methane from rice fields, ruminant animals, burning of crop residue and animal manure management. The mitigation options are to be adopted to reduce these emissions from rice fields and ruminant animals.

  The second important gas is nitrous oxide, though its actual emission is low, but in view of its warming potential, it is also contributing significantly to climate change. Its main sources are Nitrogen fertilizers (both chemical and biological) and animal waste. The main greenhouse gas carbon dioxide is also being emitted but since agriculture is also a sink for carbon dioxide its net contribution is not well known. However, efforts are to be made to reduce these emissions also by reducing tillage operations.

3.5 TERMINAL QUESTIONS

1. Identify two impacts of agriculture on environment that you think are the most negative impacts of agriculture.
2. What types of agricultural practices are responsible for soil degradation?
3. How secure is India with respect to water resources? Suggest ways in which we can improve water security.
4. What are pesticides and why are they used in agriculture?
5. How can methane emission from rice fields be reduced?
6. Why is global warming known as greenhouse effect? And why is climate change being linked with emission of green house gases?
7. Is agriculture responsible for global warming? If so, to what extent?
8. Which greenhouse gases are emitted by agricultural practices?
9. What is the warming potential of methane / nitrous oxide as compared to that of carbon dioxide? What agriculture practices emit carbon dioxide?
10. How is methane produced from rice fields? What agricultural practices can reduce methane emission from rice fields?
11. What is nitrous oxide and why is it classified as a greenhouse gas?

REFERENCES

1. Abrol, I.P. and Sehgal, J: Degraded lands and their rehabilitation in India. In Soil Management for Sustainable Agriculture in Dry Land Areas; Indian Soc. Soil Sc. pp. 107-118.
2. Agnihotri, N.P. (1999) Pesticide – Safety Evaluation and Monitoring, All India Coordinated Projecton Pesticide Residues, IARI, New Delhi.
3. Greenhouse gas emissions in India for the base year 1990: Scientific Report No.11, May 1998, Eds.: Bhattacharya, S. and Mitra, A.P.
4. "Improving the productivity and sustainability of rice-wheat systems: Issues & Impacts" American Society of Agronomy Special Publication (ASA 65) 2003 Eds.: Gupta, R.K. and Ladha, J.K.
5. "The green revolution turns sour" Devender Sharma, New Scientist July (2000), pp. 44-45.

6. Dr. M.S. Swaminathan's article on 'Greening a Nation' published in Times Agricultural Journal Nov.-Dec., 2001, pp.12-13.

7. Methane emissions from major rice ecosystems in Asia (2000); Eds. Wassmann, R., Lantin, R.D. and Neue, H.U., published by Kluwer Academic Publishers, Dordrecht / Boston / London.

8. Climate Change (1995) Eds Watson, R.T., Zinyowera, M.C., Moss, R.H. and Dokken, D.J. Published for IPCC by Cambridge Universe Press, pages 877.

9. Environmental Impact Assessment for Farms (2000) Published by Secretary General Asian Productivity Organization, Tokyo.

10. htpp://www.ghg.online.org