UNIT 6 BIOMASS BURNING

Structure

6.1 Introduction

Biomass burning is the burning of vegetation. It may be the human-initiated burning of vegetation for land clearing and land-use change as well as natural, lightning-induced fires. The practice of biomass burning is not new. For several decades, farmers have burned stubble and followed crop residue burning practices in fields and farmlands as an inexpensive and efficient way of controlling weeds, insects, diseases, and excess crop residues. Recently, crop residues have often been field burnt post harvests in a couple of days to prepare for planting the next season's crops. However, the studies have shown that, although there are some short-term benefits to burning biomass, there are long-term detrimental effects on soil quality and the overall reduction in soil health and its function that will ultimately result in reduced productivity that cannot be overcome by increased additions of mineral fertilizers.

Crop biomass is an abandoned natural resource, not waste materials that require disposal. About 25% of N and P and 50% of S and 75% K uptake by cereal crops are retained in the harvested biomass, making them valuable nutrients. It is estimated that the burning of one ton of rice straw accounts for the loss of 5.5 Kg nitrogen (N), 2.3 Kg phosphorus (P), 25 Kg potassium (K), and 1.2

Kg sulfur (S). Crop biomass is the primary source of carbon inputs, and how these are managed has a significant effect on soil's physical, chemical, and biological properties. In addition, crop biomass is the source of plant nutrients and is an essential component for the stability of agricultural ecosystems. Open field biomass burning also causes severe air pollution, public health risk and potential climate impact. Thus, it is one of the significant issues of concern for agriculture and society. This unit emphasizes the causes, extent and intensity of biomass burning; impacts of biomass burning and sustainable alternatives to biomass burning.

6.2 OBJECTIVES

After studying this unit, you should be able to:

- define biomass burning;
- explain the causes of biomass burning;
- explain the extent and intensity of biomass burning;
- explain the impacts of biomass burning and
- discuss the sustainable alternatives to biomass burning.

6.3 BIOMASS BURNING

It refers to the burning of living and dead vegetation either by natural induced fires, i.e., forest fires ignited by lightning strikes, or human-made (anthropogenic) fires, i.e., combustion of the forests and grassland for agricultural uses. Presently, anthropogenic burning makes up more than 90% of the fires on the planet. These fires damage forests and destroy the habitats for many plant and animal species, but the fires release large amounts of gasses and particles into the atmosphere. 'Prescribed burning' is a term used to describe the deliberate use of fire for management purposes. It is a significant source of various types of airborne particulate matter. It traces gasses that influence the quality of air, ground-level ozone concentration, and impact on the global climate.

6.4 CLASSIFICATION OF BIOMASS BURNING

6.4.1 Forest Fire

Forests are the main part of the terrain ecosystem and play a significant role in maintaining the balance of the terrain ecosystem. The forest coverage is very limited. However, during the last few decades, the number of forest fires and burned areas has drastically increased due to deforestation. Forest fires have impacted the biosphere-atmosphere interface, atmospheric chemistry, the composition of the ecosystem system and its distribution, environmental degradation, and air quality monitoring. In addition, they emit significant amounts of trace gases (both chemically active and greenhouse gases), non-methane hydrocarbons, and aerosols. These aerosols and pollutants significantly affect atmospheric chemistry, cloud properties, Earth radiation budget and climate change, global carbon cycle, ecosystem and biodiversity, vegetation, rainfall, air quality, and atmospheric circulation.

6.4.2 Agricultural Straw Open Burning

India is among the major agricultural nations in the world. Although agricultural crop production generates tremendous amounts of agricultural residues during the summer/autumn harvest season, a significant amount of farm straws are removed by burning in a short period to prepare for the next crop planting. Open burning is the most convenient and less expensive way to eliminate agricultural straw. It is well known that the impact of agricultural straw open burning on heavy haze formation during and shortly after the harvest seasons is complex and contributes to primary PM2.5 emissions and includes the potential contribution to the secondary PM2.5 formation.

6.4.3 Wood and Straw Combustion as Fuel

Approximately more than half of India's population lives in rural areas and uses biomass fuels (such as timber and straw) as the domestic fuel for cooking/heating. Wood and straw combustion fuel burnt in low-efficient stoves, which generally produce much smoke and substantial air pollutants. It is associated with adverse health impacts such as pneumonia, tuberculosis, and chronic obstructive pulmonary disease.

6.4.4 Miscellaneous

Apart from traditional field burning and domestic use of biomass waste, co-firing with coal or municipal solid waste (MSW) in power stations or incineration plants is indeed a practical method to deal with biomass waste, and many studies have focused on the development of combustion technologies and emission control of pyrogenic pollutants

6.5 SMOKE FROM BIOMASS BURNING

Fire is a chemical reaction sometimes called rapid oxidation. When a fire is first lit, the moisture is driven off. As it gets hotter, chemical reactions through which biomass rapidly reacts with the oxygen in the air, producing intense heat and light. Biomass burning involves three stages: ignition, flaming (burning and smoking with flame), and smoldering (burning and smoking without flame). Smoke contains the unburnt portion of these gases. Smoke is a complex mixture of many chemicals and gases, including carbon dioxide, water vapour, carbon monoxide, significant amounts of particulates (solid carbon combustion particles), hydrocarbons, nitrogen oxides, and thousands of other compounds.

Particles from smoke tend to be tiny less than one micrometre in diameter. Their size can classify particles, referred to as their "aerodynamic diameter". Coarse particles are those between 10 and 2.5 micrometres (μm) in diameter. Fine particles are smaller than 2.5 μm, and ultrafine particles are less than 0.1 μm. Smoke is a primary source of aerosol and gaseous pollutants in the atmosphere, potentially impacting global air quality and climate chemistry (Yang et al., 2008; Allen et al., 2017). The open burning results in perturbations to the local atmospheric chemistry due to trace gases and aerosols emissions, a health hazard to local inhabitants (Wang and Christopher, 2003). Studies suggest that biomass burning has increased globally over the last 100 years. They also indicated that hotter earth resulting from global warming would lead to more frequent and larger fires.

6.6 CAUSES OF BIOMASS BURNING

Open-field burning of crop biomass is a simple method for farmers to clean agricultural land after crop harvest to facilitate soil tillage. Plant biomass burning has proved to be efficient in controlling insects, diseases, and the emergence of invasive weed species. However, as a general practice, its use has been questioned for several reasons, such as nutrient loss, environmental degradation, and loss of soil organic matter, which may contribute to the overall deterioration of agricultural soil productivity (Stan *et al.,* 2014*).* The rationale for burning as a crop residue management technique by farmers is as follows:

- Burning is an essential cultural tool that removes large quantities of crop residue and enables the timely and successful establishment of high-value crops with minimal cultivation in a more weed, pest, and disease-free environment.
- Residue burning reduces the risk of untimely operations and subsequent crop failure.
- Burning cereal residues means fewer cultivation passes resulting in increased soil moisture retention, fine soil tilth, and better soil structure. Stubble burning can also improve weed control.
- Large quantities of crop residue on or close to the soil surface can restrict herbicide choice and increase herbicide resistance risk.
- Stubble burning lowers the cost of production on farms by reducing agrochemical usage, machinery costs and the number of cultivation passes.

6.7 EXTENT AND INTENSITY OF BIOMASS BURNING

India is an agrarian economy where a vast majority of the land is used for agriculture, and a wide range of plants are grown in its different agro-ecological regions. According to MoA, Govt. of India, the country had a production of 94 million tons (Mt) of wheat, 106 Mt of rice, 21.6 Mt of maize, 20.7 Mt of millets, 357.7 Mt of sugarcane, 8.1 Mt of fibre crops (jute, mesta, cotton), 17.2 Mt of pulses and 30.0 Mt of oilseeds crops, in the year 2012-13. Among the different crop categories, 361.85 Mt of residue was generated by cereal crops, followed by fibre crops (122.4 Mt) and sugarcane (107.5 Mt). The cereals crops produced 58% of residue while rice crop alone contributed 53% and wheat ranked second with 33% of cereal crop biomass. Fibre crops contributed 20% of biomass generated, with cotton ranking first (90.86 Mt) with 74% crop biomass. Sugarcane residues produced 17% of the total crop residues. The oilseed crops produced 28.72 Mt of residue annually (Pathak et al., 2012).

The burning of stalks and stubble during the wheat and rice harvesting seasons in the Indo-Gangetic plains resulted in a substantial increase in trace gases and particulate matter emissions. It negatively impacts the environment and economy as this straw is wasted and has grave implications for health and society due to the smoke and fumes produced. Punjab and Haryana are burning almost 30 million tons of biomass annually. These two states contribute to 48 per cent of the total emission due to paddy burning across India. On-farm burning of biomass has been intensifying in recent years due to the shortage of human labour, the high cost of removing the crop biomass by conventional methods, and the use of combines to harvest crops. The biomass of rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard, and groundnut are typically burnt on-farm across different states of the country. According to the IPCC, 25% of the crop biomass is burnt on the farm. The problem is more severe, particularly in the mechanized rice-wheat cropping system of NW India (Fig. 6.1). The summer wheat residue burning season happens from April to May, while in the winter season, rice residue burning is mostly seen during October and November. The crop residue burning in northwest India causes an immense pollution problem in Delhi and the NCR region of India.

According to MNRE (2009), the crop biomass generation was 500 Mt, and the surplus was 141 Mt (Table 1). However, according to Sardar Patel Renewable Energy Research Institute (2004), about 72 Mt crop biomass is burnt on-farm. Recently, Pathak et al. (2010) have concluded that about 93 Mt of crop biomass is burnt on-farm.

According to National Biomass Resource Assessment (NBRA), 23 % of the total rice straw produced in the field is surplus. Punjab and Haryana contribute 48 % and Uttar Pradesh 14 % of the total subject to open field burning. Therefore, this study estimates a 13.92 Tg quantity of rice straw burning in the open fields.

Fig.6.1. Burning of rice biomass is a widespread practice in northwest India

Table 6.1. Crop biomass burnt in various states of India

States	• Residue generation (MNRE, 2009)	• Residue surplus (MNRE, 2009)	Residue burned (Pathak et al. 2010)
Andhra Pradesh	43.89	6.96	2.73
Arunachal Pradesh	0.4	0.07	0.04
Assam	11.43	2.34	0.73
Bihar	25.29	5.08	3.19
Chhattisgarh	11.25	2.12	0.83
Goa	0.57	0.14	0.04
Gujarat	28.73	8.9	3.81
Haryana	27.83	11.22	9.06

Himachal Pradesh	2.85	1.03	0.41
Jammu and Kashmir	1.59	0.28	0.89
Jharkhand	3.61	0.89	1.10
Karnataka	33.94	8.98	5.66
Kerala	9.74	5.07	0.22
Madhya Pradesh	33.18	10.22	1.91
Maharashtra	46.45	14.67	7.41
Manipur	0.9	0.11	0.07
Meghalaya	0.51	0.09	0.05
Mizoram	0.06	0.01	0.01
Nagaland	0.49	0.09	0.08
Orissa	20.07	3.68	1.34
Punjab	50.75	24.83	19.62
Rajasthan	29.32	8.52	1.78
Sikkim	0.15	0.02	0.01
Tamil Nadu	19.93	7.05	4.08
Tripura	0.04	0.02	0.11
Uttarakhand	2.86	0.63	21.92
Uttar Pradesh	59.97	13.53	0.78
West Bengal	35.93	4.29	4.96
India	**501.76**	**140.84**	**92.81**

Source: Pathak et al., (2012).

6.8 IMPACTS OF CROP BIOMASS BURNING

Biomass burning is one of the leading causes of air pollution during winters, leading to the deterioration of air quality in North India. The issue of crop residue burning has to be addressed holistically.

6.8.1 Soil Nutrients

During combustion, 50-70% of the crop biomass carbon is commonly volatilized to CO_2 and CO, although losses of up to 90% have been measured when combustion of the residue is almost complete. The remaining carbon is returned to the soil surface as charred residue, which is not biologically active. Consequently, burning can alter both the quantity and the quality of organic matter in the soil (Pathak et al. 2012). The ash from stubble burning is alkaline, which can immediately increase the pH at the soil surface. In general, losses of nutrients due to burning decrease in the order N > Ca > S > K > Mg > P > Na. These losses depend on the heat reached in soil layers during burning. Volatile losses of P and K occur at temperatures exceeding 500°C, whereas the vaporization of Na is reported at temperatures exceeding 880°C. However, this temperature may not be achieved during the burning of cereal crop biomass or grass/legume pastures, and most of these elements are left in the ash (Kumar & Goh 2000).

Crop residue contains nutrients that can be recycled to replace part of the nutrients removed by grain harvest. Cereal crop biomass comprises approximately 15% of the N and P, 36% of the S, and 80% of the K present in wheat at maturity. Burning crop biomass results in an immediate increase in extractable phosphorus and potassium content in the surface 0-2.5 cm soil layer, although no long-term build-up of these nutrients is observed (Prasad & Power 1991). The majority of the nitrogen, carbon, and sulfur in burned biomass will be escaped into the atmosphere as gases, but the other nutrients present in the biomass, such as phosphorous, potassium, calcium, and magnesium, will often be returned to the soil as ash biomass. Estimates of losses of N to the atmosphere during burning are in the order of 30-90%, depending on the extent of combustion. That represents a loss of 10-25 kg N ha^{-1} for a straw crop of 5 tons per hectare. Like phosphorus (P) and potassium (K), the nutrients are typically retained after burning. Nutrient content in harvested straw and ash from different crop biomass is shown in Table 6.2.

Table 6.2. Nutrient content in harvested straw and ash from various crop biomasses

Nutrient	Material	Spring wheat	Oats	Flax
Carbon (%C)	Straw	40.0 - 42.0	39.8 - 40.1	45.7 - 46.2
	Ash	8.6 - 29.4	9.2 - 28.8	27 - 51
Nitrogen (% N)	Straw	0.66 - 1.28	0.26 - 1.02	0.68 - 1.04
	Ash	0.42 - 1.76	0.25 - 0.71	0.93 - 1.87
Phosphorus (% P)	Straw	0.09 - 0.19	0.04 - 0.12	0.04 - 0.10
	Ash	0.92 - 1.02	0.50 - 1.02	0.40 - 2.20
Potassium (% K)	Straw	0.67 - 2.21	1.37 - 3.31	0.19 - 0.29
	Ash	3.1 - 16.6	9.35 - 29.45	2.49 - 4.97
Sulfur (% S)	Straw	0.06 - 0.16	0.01 - 0.50	0.05 - 0.07
	Ash	0.05 - 0.55	0.10 - 3.30	0.11 - 0.29

Range of values = average (mean) value minus or plus one standard deviation

Source: www.servitechlabs.com

6.8.2 Greenhouse Gas Emissions

Agricultural activities are significant producers of CH_4 and N_2O (IPCC, 2018). Of the three most important gases influenced by land management and responsible for the potential greenhouse effect, CO_2 has the greatest climate forcing potential (57%), while CH_4 and N_2O account for 27% and 16%, respectively. Modern agriculture contributes to atmospheric greenhouse gasses (GHG) with about 14% of global net CO_2 emissions (IPCC, 2007). It has been reported that field burning of crop biomass represents a significant source of greenhouse gasses and aerosols. Field biomass burning converts many nutrients into gaseous form, then lost from the site (Haider, 2013). Badrinath *et al.* (2006) estimated the greenhouse gas (GHG) emissions from rice and wheat straw burning in Punjab during May and October 2005 and suggested that emissions from wheat crop biomass in Punjab are relatively small compared to those from paddy fields.

6.8.3 Air Quality

Crop residue burning is one of the many sources of air pollution. It is the largest source of primary carbonaceous, fine aerosols and the second most important source of trace gasses. Species directly emitted from biomass burning include CO_2, CH_4, CO, NOx, NH_3, non-methane organic compounds (NMOCs), carbonyl sulfide (COS), SO_2, and elemental and organic carbonaceous and sulfate-containing particles. Secondary species formed from biomass burning precursors include ozone (O_3), oxygenated NMOCs, and inorganic and organic aerosol. Globally, crop residue burning is estimated to produce 40 per cent of the carbon dioxide, 32 per cent of the carbon monoxide, 20 per cent of the particulates, and 50 per cent of the highly carcinogenic polyaromatic hydrocarbons produced by all sources (Levine, 1990). In Asia, the annual contribution from open-field biomass burning is estimated to emit 0.37 Tg of SO_2, 2.8 Tg of NOx, 1100 Tg of CO_2, 67 Tg CO, and 3.1 Tg methane (CH_4) (Streets *et al*., 2003).

According to Mandal et al. (2004), the total crop residue generated in India is estimated at 350×10^6 kg $year^{-1}$, of which wheat residue constitutes about 27 % and rice residue about 51 %. A study by Badrinath et al. (2008) shows that approximately 5,504 km^2 of the wheat crop area was burnt during May 2005, with the average biomass in the field after harvesting at about 5.94 t ha^{-1}. While for paddy, about 12,685 km^2 of the area was burnt during that period. The result of the study on crop residue burning and its emission contribution is summarized in Table 6.3. Gupta et al. (2004) showed that the burning of straw also emits an enormous amount of particulates composed of a wide variety of organic and inorganic species. One ton of straw on the burning releases particulate matter, 60 kg CO, 1,460 kg CO_2, 199 kg ash, and 2 kg SO_2. These gases and aerosols consisting of carbonaceous value have an essential role in the atmospheric chemistry and can affect the local environment and also has linkages with global climate change (Kumar *et al.,* 2014).

Table 6.3. Total emission by the burning of rice and wheat biomass

Name of the crop	Total Emissions Gg				
	CO	NO_X	CH_4	PM_{10}	$PM_{2.5}$
Wheat	113	8.6	1.33	13	12
Rice	261	19.8	3	30	28.3

Source Badrinath *et al.* (2008)

Open burning contributes 25 % of black carbon, organic matter, and carbon monoxide emissions, 9–13 % of $PM_{2.5}$ and CO_2 emissions, and 1 % of SO_2 emissions (Venkataraman et al. 2006). Table 6.4 gives the national estimates of biomass burned and emission of aerosols and trace gases for crop waste open burning. The crop residue burning in the fields ranges from 18 to 30% and has substantial regional variations.

Table 6.4. National estimates of biomass burned and emission of aerosols and trace gasses

Pollutants	Crop biomass burning (Emission factors Gg $year^{-1}$)				
	Cereals	Sugarcane	Others	Total crop waste	Total open burning
Biomass burned Tg $year^{-1}$	67–189	32–70	17–30	116–289	148–350
Black carbon (BC)	55–292	19–49	12–31	86–372	102–409
Organic carbon (OC)	134–770	48–122	39–79	211–970	399–1,529

Organic matter (OM)	287–1,250	97–247	60–143	444–1,639	663–2,303
$PM_{2.5}$	369–1,913	125–289	78–191	572–2,393	851–3,317
CO_2 (Tg $year^{-1}$)	102–353	48–131	25–55	175–539	224–638
CO (Tg $year^{-1}$)	6–49	3–18	2–8	10–74	13–81
SO_2	27–113	13–42	7–18	46–172	66–238
NO_X	168–845	80–313	42–132	289–1,290	393–1,540
CH_4	181–762	86–283	45–119	313–1,164	420–1,486
NMVOC	1,055–4,430	500–1,644	263–693	1,818–6,767	2,039–7,406
NH_3	87–367	41–136	22–57	151–560	189–661

Source: Venkataraman et al. (2006)

The complex mixture of reactive gases and aerosol that make up biomass burning plumes can act as short-lived climate forcers (Keywood et al., 2011). While biomass is burning, plumes often have the most significant impact on the atmosphere close to the source of the fire. Once injected into the free troposphere, plumes may travel long distances, so climate and air quality effects may be regional or global. For example, a recent modelling study by Lewis et al. (2013) highlighted the significant contribution that biomass burning emissions make to the burden of several NMOC in the background atmosphere, particularly in the Southern Hemisphere. It has been shown that polluted air masses resulting from fires in Brazil can be transported over the tropical Atlantic towards Africa and the Indian Ocean (Singh et al., 1996); plumes originating from Alaskan fires in 2004 have also been detected in Europe, leading to an increase in the ozone background concentration, and even to high ozone episodes (Real et al., 2007). During October- November, a vast cloud of smoke engulfs the Punjab state, India, as farmers burn the stubble of freshly harvested rice. Smog engulfed several parts of Delhi after farmers in Haryana and Punjab continued to burn paddy stubble in their fields.

6.8.4 Health

The ill-health effects of biomass burning are well-established. Smoke from crop biomass burning is hazardous since most particulates are smaller than 10 microns in size (PM10) and can easily travel deep into the lungs. Numerous studies have noted that increasing levels of PM_{10} (even if below the US EPA standard of 50 micrograms PM_{10} per cubic meter of air) can significantly increase levels of respiratory and heart problems (Morris, 2001). Long et al. (1998) studied the health outcomes from biomass burning through a survey of 428 participants with underlying respiratory disorders and exposure to pollution from the burning of crop residue, affirmed that people with underlying respiratory diseases were sensitive to the air pollution caused by biomass burning. Furthermore, their study found that the infection either aggravated underlying symptoms or induced additional air-pollution-related symptoms.

The burning of crop waste also has adverse implications for the health of milk-producing animals. Air pollution can result in the death of animals as the high levels of CO_2 and CO in the blood can transform normal haemoglobin into deadly haemoglobin. There can also be a potential decrease in the yield of the milk-producing animals (Kumar *et al.,* 2014). Pregnant women and children are also likely to suffer from the smoke produced due to stubble burning. Moreover, inhaling fine particulate matter of less than PM2.5 triggers asthma and can even aggravate symptoms of the bronchial attack. According to Singh et al. (2008), more than 60 % of the peoples in Punjab live in rice-growing areas and is exposed to air pollution due to the burning of rice stubbles. As per the same study, medical records of the civil hospital of Jira in the rice-wheat belt showed a 10 % increase in the number of patients within 20–25 days of the burning period every season (Kumar *et al.,* 2014).

6.9 SUSTAINABLE OPTIONS AND ALTERNATIVES TO BIOMASS BURNING

The biomass produced during the harvesting of crops can be used for various alternative uses if it is not burnt. Several options can be practised to manage biomass productively. Biomass can be used as cattle feed and compost. It can also be used for energy generation, biofuel generation and mushroom cultivation. As it was already argued, sequestration of C from plant biomass into soil organic matter (SOM) is a key sequestration pathway in agriculture. Thus, there are multiple benefits to sequestering C in the forest and agricultural soils, beyond the apparent use of offsetting CO_2 emissions (Johnson *et al*., 2007).

6.9.1 Biomass Management Practices

In India, biomass residue management is crucial in the rice-wheat cropping system because large quantities of plant biomass are left on the ground surface, mainly when combine machines are used for crop harvest. It has been reported that the rice-wheat system is producing about 10.0 tons ha^{-1} yield exhausts about 500 kg ha^{-1} of NPK and other trace elements from the soil. Several options for agricultural crop biomass utilization can be practised to manage biomass productively.

1. Composting of Biomass for Manure

The biomass can be composted by using it as animal bedding and then heaping in a dung pit. Each kg of straw absorbs about 2-3 kg of urine from the animal shed. Alternative methods on the farm itself can also compost it. For example, rice biomass from one hectare gives about 3.2 tons of manure as rich in nutrients as farmyard manure (Pathak et al., 2010).

2. Biomass incorporation

As per Singh et al. (1996), if the rice residue is incorporated immediately before sowing the wheat crop, the crop yield is considerably reduced because of the immobilization of inorganic nitrogen and its adverse effect due to nitrogen deficiency. However, in a few studies, it was established that wheat yield decreased in the first 1–3 years when the rice stubble was incorporated into the soil 30 days before sowing of the wheat crop, primarily because of the immobilization of soil nitrogen in the presence of plant biomass with wide C/N ratio. However, in later years rice stubble incorporation did not affect wheat crop yield.

According to Verma and Bhagat (1992), the incorporation of rice residue 30 days before sowing of wheat crop resulted in lower wheat yields than wheat yields when the rice residue is burnt or removed from the fields. Furthermore, incorporating rice stubble in the soil impacts the soil's physical, chemical, and biological properties such as pH, organic carbon, water holding capacity, and soil bulk density. Thus, in general, biomass recycling will have agronomic, environmental, and economic advantages; however, sometimes, its mismanagement and other technical problems may result in limited uses in farmer's fields.

3. Vermicomposting

Vermicompost is an essential method in which crop biomass is converted into valuable compost using worms. Earthworms and microbes act together and break down the complex organic matter, and the resulting material is rich in nutrients and oxygen. Thus, it is an effective way to increase organic matter in the soil. In addition, increasing the organic matter of soil compost also increases the soil microbial population (Perucci, 1990), which improves soil quality. After the crop is harvested, the total biomass must go back to the soil to replenish the lost nutrient, so vermicompost is considered an excellent way to recycle nutrients in the ecosystem and an effective option to improve soil health and crop productivity.

4. Conservation Agriculture (CA)

Conservation agriculture (CA) has been introduced as a widely adopted set of management principles to ensure more sustainable crop production. CA is a broader concept than conservation tillage, a system where at least 30% of the soil surface is covered with crop biomass after seeding the next crop. In conservation agriculture, the emphasis lies in the tillage component and the combination of the following three principles. These are (i) Reduction in tillage- the purpose is to reach zero tillage (i.e., no-tillage), but the system may include controlled tillage seeding systems that usually do not disturb more than 20–25% of the soil surface. (ii) Retention of adequate levels of crop biomass and soil surface cover. (iii) Use of crop rotations, the objective, is to employ diversified crop rotations to help moderate/mitigate possible weed, disease, and pest problems.

These conservation agriculture principles apply to a wide range of crop production systems from low-yielding, dry, rainfed conditions to high-yielding, irrigated conditions. However, the application of the principles of CA will be very different from one situation to another. Distinct and compatible management components such as pest and weed control tactics, nutrient management strategies, and crop rotations will need to be identified through adaptive research with active farmer involvement. For example, under gravity-fed irrigated conditions, a permanent raised bed system with furrow irrigation may be more suitable and sustainable than a reduced or zero tillage system on the flat to replace the widely used, conventionally tilled system of flood irrigation on flat land.

6.9.2 Renewable Energy Strategy

There is an increasing interest in converting crop biomass into energy products due to new emerging technologies and their environmental benefits. In recent years, there has been an addition to the usage of crop biomass for power generation and as an excellent alternative to fossil fuels. It also gives an instant solution for the reduction of CO_2 concentration in the atmosphere. Compared with other renewable energy resources such as solar and wind power, biomass is a storable resource, inexpensive, energy-efficient, and environment-friendly.

1. Electricity Generation from Crop Biomass

Several studies indicate the potential of electricity generation from crop residues. However, straw is characterized by low bulk density and low energy yield per weight basis. In addition, the logistics of transporting the large volumes of straw required for efficient power generation represents a significant cost factor irrespective of the bioenergy technology. Therefore, biomass availability, transportation cost, and infrastructural settings (harvest machinery, modes of collection, etc.) drive biomass for energy generation.

2. Liquid or Gaseous Biofuel from Crop Biomass

Using thermochemical or biological techniques, liquid or gaseous biofuel can be produced from crop biomass like cereals and corn. The conversion of lignocellulosic biomass into bio-based ethanol production is of immense importance. It is a researchable issue as it can be either blended with gasoline as a fuel extender and octane-enhancing agent or used as a neat fuel in internal combustion engines. The theoretical estimates of ethanol production from different feedstock (corn grain, rice straw, wheat straw, bagasse, and sawdust) vary from 382 to 471 L t^{-1} of dry matter.

3. Bio-methanation

Biomass such as rice straw can be transformed into biogas, a mixture of carbon dioxide and methane. It is stated that biogas of 300 m^3 t^{-1} of dry rice straw can be obtained. The process yields a high gas quality with 55-60% methane, and the spent slurry can be used as manure in the crops. This process promises to utilize plant biomass in a non-destructive way to extract high-quality fuel biogas and produce waste to be recycled in soil.

4. Gasification of Biomass

Gasification is a thermochemical energy production process in which gas is formed due to the partial combustion of biomass. The process breaks down biomass entirely to yield energy-rich gaseous products after initial pyrolysis. The major problem in biomass gasification for power generation is gas purification so that impurities are separated. The biomass can be used in the gasifiers for the creation of producer gas. In some states, gasifiers with more than 1MW capacity have been introduced to generate producer gas. One ton of biomass can be used for the production of 300 kWh of electricity.

5. Fast Pyrolysis

Fast pyrolysis of crop biomass needs the temperature of biomass to be raised to 400-500 ^{o}C within a few seconds. This results in a striking change in the thermal disintegration process. About 75% of the dry weight of biomass is transformed into condensable vapours. If the condensate cools rapidly within a couple of seconds, it yields a dark brown viscous liquid commonly called bio-oil. The calorific value of bio-oil varies from 16-20 MJkg^{-1}.

6. Biochar

Biochar is the leading carbon material produced from biomass's slow pyrolysis (heating in the absence of oxygen). It has benefits regarding its efficiency as an energy source, its use as a fertilizer when incorporated into the soil, and its ability to stabilize and reduce emissions of harmful gases into the atmosphere. Biochar finds utilization in releasing energy-rich gases used to produce liquid fuels or directly for power and heat generation. It can potentially play a significant role in the long-term storage of carbon. Moreover, biochar improves the fertility and water retention capability of the soil and increases the rate of mineral transport to the roots of the plants.

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1. Explain the causes of biomass burning.

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2. Discuss the extent of biomass burning in India.

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3. Explain the impacts of crop biomass burning.

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4. Explain the sustainable alternatives to crop residue burning.

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6.10 LET US SUM UP

Crop biomass is an abandoned natural resource, not waste materials that require disposal. A significant portion of unused crop biomass is burnt in the fields to clear the left-over straw and stubbles after the harvest. The burning of crop biomass creates environmental pollution, is hazardous to human and animal health, produces greenhouse gases causing global warming, and loses plant nutrients. About 25% of N and P and 50% of S and 75% K uptake by cereal crops are retained in the harvested biomass, making them valuable nutrients. After the crop is harvested, the entire biomass must go back to the soil to replenish the lost nutrients. The world is focusing on conserving this natural resource.

Furthermore, intensive soil cultivation devoid of organics has resulted in the degradation of agricultural soils with the decrease in soil organic matter and loss of soil structure, adversely affecting soil functioning and causing a long-term threat to future crop yields. Therefore, appropriate management of crop biomass assumes importance. The crop biomass is a good source of plant nutrients and is an essential component for the stability of agricultural ecosystems.

6.11 KEY WORDS

Biomass Burning: It refers to the burning of living and dead vegetation either by natural induced fires, i.e., forest fires ignited by lightning strikes, or human-made (anthropogenic) fires, i.e., combustion of the forests and grassland for agricultural uses.

6.12 SUGGESTED FURTHER READING/REFERENCES

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6.13 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 6.6
2. Please refer to section 6.7
3. Please refer to section 6.8
4. Please refer to section 6.9