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Desert Locust Invasions, Their Aftermath, And the Myth Of Their Existence In The United Arab Emirates

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ABSTRACT

Insects have evolved to live in almost every habitat, from lowlands to mountaintops, deserts, and dry regions, making them some of the universe's oldest residents. There are many different kinds of insects, some of which are helpful to humans while others can seriously harm both the environment and human civilization. Due to its migration, polymorphic, and ravenous eating tendencies, the desert locust is particularly harmful. They may wreak havoc on both wild and cultivated vegetation when they form swarms, or congregations of adults, and hoppers, or congregations of nymphs. This results in a shortage of food and fodder. Due to their long development in desert regions, where food plants can only grow with the help of good rains, giving the desert locust with the ideal environment, their migratory tendency is a result.

INTRODUCTION

The desert locust may quickly consume as much food in one day which makes it a very damaging pest. The weight of the locusts can cause trees to collapse when they accumulate in large numbers. This migratory insect is also capable of quickly traveling across continents, resulting in large-scale destruction of natural vegetation and farmers' crops. Consequently, the desert locust is considered by many to be an unimaginable threat to both mankind and the environment. Since August 2019, hopper bands and swarms of desert locusts originating from Yemen have been wreaking havoc on the Horn of Africa region, comprised of Somalia, Ethiopia, Kenya, Uganda, Djibouti, and the United Arab Emirates.

The deserts of North Africa, the Middle East and Southwest Asia are the typical habitats of the solitary locusts, where they thrive on an annual vegetation made flourishing by sporadic rains, laying eggs in the moist sandy soil. This drought-stricken region, covering an area of 16 million square kilometers, is around twice the size of the United States, and encompasses over 30 countries. During periods of relative inactivity, known as recessions, the locusts remain isolated individuals. However, when there are heavy rains, they rapidly reproduce and multiply by up to 16-20 times within a period of three months, introducing a new generation and causing immense damage. With the increase in their population density, the locusts deplete the food resources in their immediate environment, forcing them to form bands and swarms and move on to invade other areas in search of sustenance.

LIFE CYCLE OF DESERT LOCUST

Desert locusts undergo three stages of development: Egg, Hopper/Nymph, and Adult. The length of each of these stages is highly dependent on the weather and food availability. Depending on the conditions, desert locusts can transition between solitary and gregarious phases. On average, desert locusts can complete 2-5 generations per year. Generally, they move during the day as temperatures rise, though they may occasionally move at night during warm days or under a full moon. Warmer temperatures tend to result in a shorter life cycle than cooler temperatures of the stages in the life cycle, the Hopper (3rd to 5th instars) and immature adult stages are the most active, though the immature stage is the most destructive due to its mobility and high food consumption.

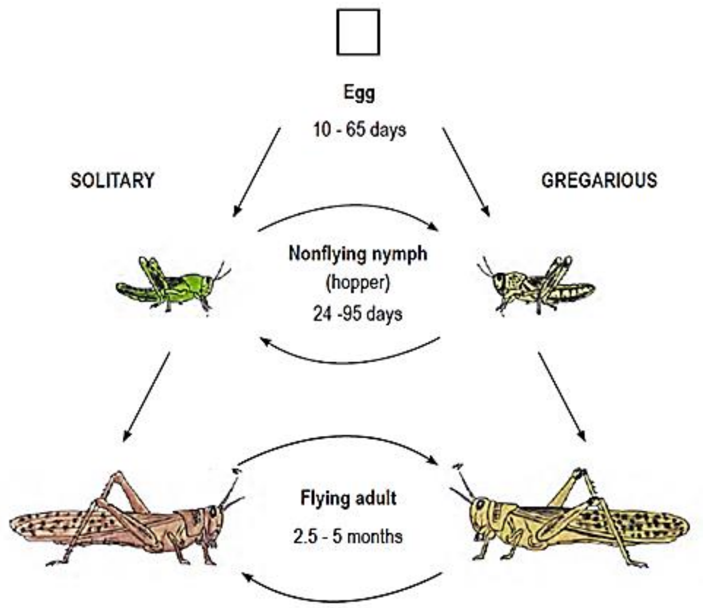

Fig 1: Life cycle of a Desert Locust

EGG STAGE

Females of this species lay eggs in batches, known as egg pods, in moist soil 10-15 cm below the surface. Solitary females typically deposit 3-4 egg pods containing 100-160 eggs, while gregarious females deposit 2-3 egg pods containing 60-80 eggs. The length of the incubation period for the eggs can vary greatly, ranging from 10 days to 70 days depending on the temperature and soil moisture of the environment; this period is usually between 10-14 days in summer breeding regions and 25-30 days in cooler regions, extending up to 70 days in North Africa.

Fig 2: A female laying (Left), Eggs laid in the soil (Right)

Fig 3: Adult female locust laying eggs in the sand (Left), Desert locusts mating (Right)

HOPPER STAGE

The development of hoppers across the instar stages involves a gradual moulting to increase in size. The solitary phase goes through six instar stages, which are all uniformly green in colour, whereas the gregarious phase undergoes five instar stages, with the first being black and the remaining having a distinct black and yellow pattern. Hopper development can take anywhere from 22 days in warm temperatures (37^0 C) to up to 70 days in cool temperatures (22^0 C). To regulate their body temperature, hoppers bask in the early morning and roost at midday. Green vegetation is essential for hoppers as it provides food and shelter. Unfortunately, large mortality commonly occurs in the first instar stage due to cannibalism and predation, and not all hoppers that emerge from this stage make it to the fledged young adult stage. To identify hopper stages, it is helpful to note that the solitary phase has six instars, with the last two sometimes turning brown, while the gregarious phase has five instars, with the first being black and the remaining having a black and yellow pattern.

ADULT STAGE

The size of adults does not expand, although they may put on weight; normally, females are bigger than males. Maturing usually occurs during the rainy season, although under dry conditions, the process can take up to 6 months, while in more favorable ecologies, it can be as short as two to four weeks. Males mature earlier and secrete hormones that promote female maturation. Once mature, adults do not feed or move much, as they look for suitable breeding grounds and mate, with their life span lasting between three and six months, depending on local weather and environmental conditions.

SOLITARIOUS ADULT

Immature adults of this species are generally pale grey to brownish in hue, but males become a pale yellow upon maturity. Females remain the same colour. They are not as active as other species, and migrate mainly at night. At a temperature of 27^0 C or higher, they are capable of taking off and can fly for up to 10 hours.

GREGARIOUS ADULT

Fledglings take around 10 days to strengthen their wings to the point of being able to fly. Once their wings have hardened, the locust is then referred to as an immature adult and appears pink in colour. Immature adults are highly mobile and voracious feeders, making them very destructive. Mature adults, typically yellow in hue (particularly in males), migrate during the day, taking off two to three hours after sunrise in warm weather and four to six hours in cooler conditions. They can fly up to 150 to 200 kilometers in a day, often settling just before sunset to roost on vegetation, before descending to the ground in the morning to bask in the sun.

WHAT IS THEIR GOAL?

The migratory behavior of the desert locust is essential for its survival. They move in the form of hopper bands and swarms of adults during the day, and can also fly solo during the night. The urge to migrate is further intensified due to the cannibalistic tendencies of these insects. To keep a positive check, each country has its own locust warning organization that carries out surveys, surveillance and control operations. Migration is especially encouraged when favorable weather conditions, such as rainfall, occur, as this triggers breeding and the growth of plants which provide food. Winds play a major role in the migration and push the adults to areas where rainfall is expected to occur.

The migratory behavior of locusts consists of two phases: Solitarious (at night) and gregarious (by day). These insects have high resistance, and will only lay eggs when conditions are suitable for breeding. Since they cannot stay in the same place for long, they must consume local resources and then migrate in order to ensure their survival. Heavy rains also provide favorable conditions for breeding, resulting in sudden population increases. The eggs are laid in sandy or sandy clay soils and vegetation, with the two main factors affecting their development being rains and availability of vegetation. This can lead to the formation of hopper bands, followed by swarms and then outbreaks and eventually, an invasion, if no preventative measures are taken in time.

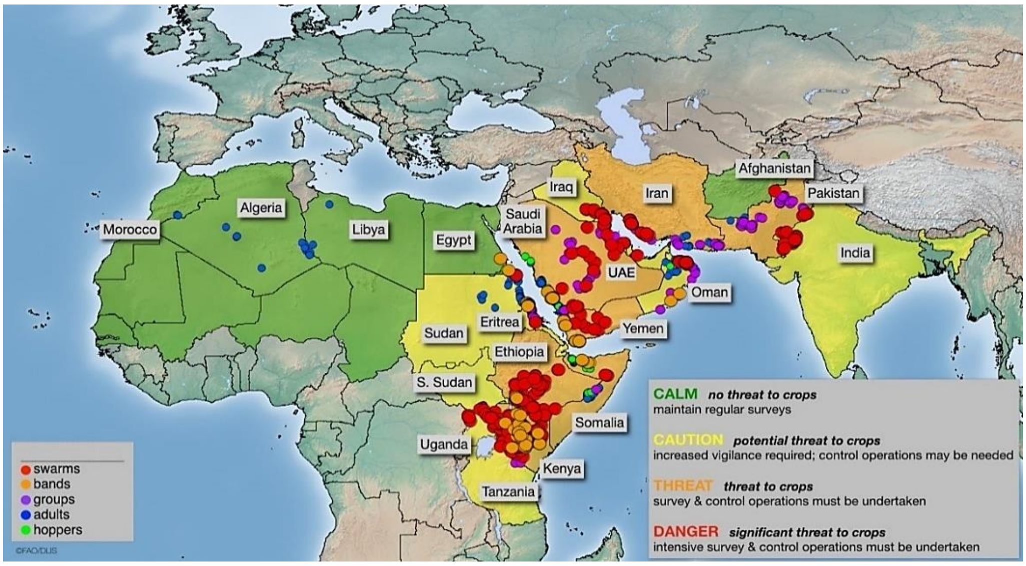

Fig 4 (a): Distribution, invasion, and global forecast of desert locust February 2019

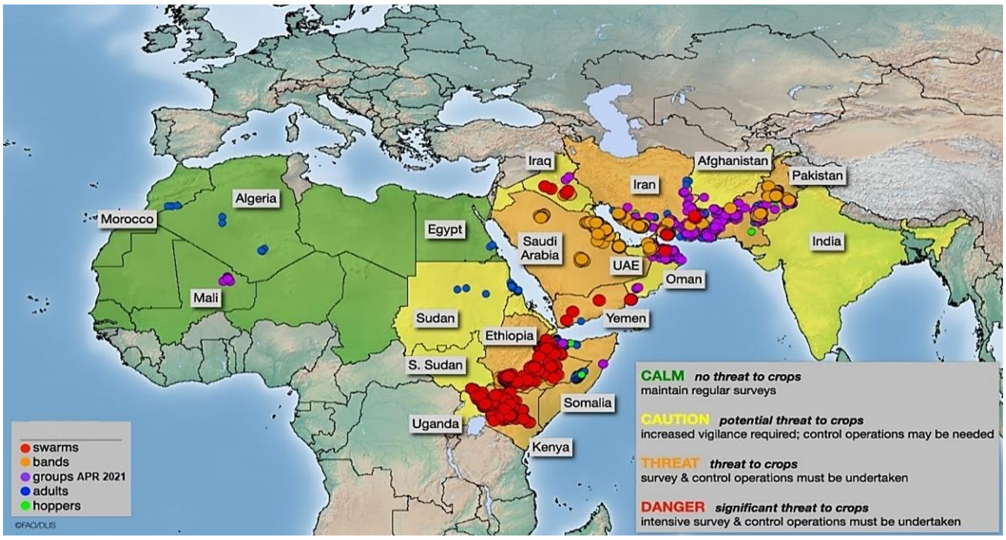

Fig 4 (b): Distribution, invasion, and global forecast of desert locust April 2020

WHAT HAS THE GOVERNMENT PUT IN PLACE TO MONITOR THE LOCUST OUTBREAK?

The government undertook a concerted effort to tackle what farmer termed "Infiltrationists." This was followed by a massive infestation of locusts in the United Arab Emirates, concentrated mainly in the Al Dhafra and Al Ain Region. These pests caused damage to over 85,948 donums of land, and were observed by government officials on 11-12 February 2019. What made this infestation so unusual was that these were not ordinary grasshoppers, but desert locusts, the same migratory pests that have devoured acres of maize, alfalfa, and date palms in East Africa. Control teams monitored the locusts' presence in the western, northern, and eastern regions of the country, as well as along the India-Pakistan border. This occurred at a time when the UAE was already struggling to contain the most severe new coronavirus pandemic.

Local authorities in Abu Dhabi have handled over 73,930 donums of infested areas with tractor-mounted sprayers and other vehicles, treating them with insecticides such as Deltamethrin and Lambda-Cyhalothrin. It takes about a liter of the chemical to treat a hectare of the locusts' breeding areas, including the trees they rest in at night. Pesticides are plentiful for controlling swarms, but the new lock-down system does not provide much time for the necessary activities for controlling the outbreak, such as equipment procurement, field engineers, spraying workers, field team training, supply pre-positioning in key breeding areas, and contingency plans updating. Unfortunately, agriculturists in some areas have lost their entire crops due to the locusts.

CONCLUSION

The outbreak of desert locust invasions is dependent on the rains and associated vegetation. In 2019, due to a lack of rains, the locust population was very low and nearly nonexistent in the Atlantic and Middle East. However, during the second half of April and October 2019, a strong tropical cyclone in the Arabian Sea brought heavy rains to Yemen, Oman, Northern Somalia, Eastern Ethiopia and Southern Rub-al-Khali in Kingdom of Saudi Arabia. This period of favorable conditions lasted for nine months, from June 2019 to March 2020, allowing the desert locust to develop three generations. If excessive rains occur in the breeding areas, the probability of further invasions of the locust will increase unless it is kept in check.

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Millets: From Conventional Food to Fruit Beverages

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ABSTRACT

One of the sustainable solutions for overcoming malnutrition is having a balanced diet by giving more importance to locally grown foods. In India, millets have been cultivated since ancient times; however, its production and consumption have reduced drastically due to the development of high yielding major staple food crops. In contrast, millets are nutritionally superior to other high yielding major staple food crops in terms of protein, fat, minerals, vitamins and other health promoting bioactive compounds. Therefore, there is a need to change our dietary pattern to include more millet-based products. Consumers should be provided with number of value-added products from millets which will make them to incorporate in their daily diet.

INTRODUCTION

Millets referred to as "small seeded grasses" are considered high drought-tolerant crops. Pearl millet [*Pennisetum glaucum* (L.)], finger millet [*Eleusine coracana* (L.)], foxtail millet [*Setariaitalica* (L.)], proso millet (*Panicum miliaceum*L.), barnyard millet (*Echinochloa* spp.), kodo millet (*Paspalum scrobiculatum*), and little millet (*Panicum sumatrense*) are commonly consumed. Cultivation and consumption of millets as a part of diet has been started even before the cultivation of major grains. Millets play an important role in developing countries' food and nutritional security in Asia and Africa, especially in India, Nigeria and Niger. In India, sorghum, pearl millet, finger millet, foxtail millet, kodo millet, little millet, proso millet and barnyard millet are grown in different regions. Even though these millets are considered coarse cereals, but due to their high nutritional quality, they are now called nutri-cereals (Malathi *et al*., 2016). India is the largest producer of millets in the world, sharing about 41% of total world production (FAOSTAT, 2016; Press Information Bureau, India, 2022). Madhya Pradesh is the leading producer of millet, producing about 8.8 million tonnes, whereas Uttarakhand and Tamil Nadu are leading in productivity (Anbukkani *et al*., 2017). However, cultivation and consumption have declined due to the emergence of high-yielding cereal crops such as rice and wheat. Therefore, much emphasis is given now by the government to increase its production and consumption. Owing to the nutritional quality of millets, Food and Agriculture Organization has declared the year 2023 as an International Year of Millets as was proposed by the Department of Agriculture, Cooperation & Farmers' Welfare, GOI.

NUTRITIONAL AND THERAPEUTIC IMPORTANCE OF MILLETS

The nutritional and therapeutic value of millets has been studied by the researchers and shown that millets are very good source of many nutrients and play an important role in preventing the risk of many non-communicable diseases. The carbohydrate content among the millets is ranging between 70-72.6%, protein (6.22-11.6 %) and fat (1.12-4.7%). Meanwhile, foxtail millet has double the protein content of rice and about 6-7 fold of fat content (Longvah *et al*., 2017). These millets also contain good amount of n-6 fatty acids. Millets have low Glycemic Index and thus play a very important role in controlling type II diabetes mellitus through their inclusion in diet (Nambiar and Patwardhan, 2015; Park *et al.*, 2008). It has been reported by Shimanuki *et al.*, (2006) that intake of a diet containing a proso millet protein concentrate raised plasma levels of high-density lipoprotein (HDL) cholesterol which is a good cholesterol without causing an increase in low-density lipoprotein (LDL) cholesterol (bad cholesterol) levels in rats and mice.

Study on cytotoxicity against four human cancer cell lines such as colon (HCT-116), cervical (HELA), liver (HEPG-2) and breast (MCF-7) adenocarcinoma cells by the extracts of powdered barnyard millet showed that the millet extract was cytotoxic against cancer cells (Molla *et al.*, 2016).

VALUE ADDITION IN MILLETS

Traditionally millet products such as porridge, roti and malt were being used in millet growing regions. Besides, various products have been developed using millet flour due to its nutritional quality. Processed products from cereals viz., flakes, cookies, cake, bread, atta, extruded products and malt are prepared using millet flours by replacing cereals fully or partly (Fig 1). This replacement of cereals by millets showed an increased protein content, amino acids, fibre and minerals. Fiber enriched functional bread by incorporating little millet flour up to 50% in comparison to 100% wheat flour bread has been developed by Mannuramath *et al.*, (2015). Incorporation of little millet flour upto 30% did not show significant difference in sensory parameters compared to control samples. Further, increased iron (94%), zinc (29%), copper (70%), phosphorus (28%) and fibre (19%) content was observed in bread substituted with 30% little millet compared to 100% wheat bread.

Fig 1: Different products prepared from millet flour

In another study, khichdi prepared from barnyard millet and rice was compared for their nutritional quality and glycemic index (GI). About 42% of protein, 44% of fat, 988% of crude fibre, 22% of iron and 200% of zinc was found high in barnyard millet khichdi compared to rice khichdi. Further, the GI of barnyard millet khichdi was 34.96, whereas the GI of rice khichdi was 62.50. Hence, incorporating millet in our daily diet will provide more nutrients to our bodies (Joshi and Srivasthava, 2016).

In traditional Indian foods/diets, millets were in staple diets, multi-grain additives (like multi-grain flours) or breakfast diets (liquid millet formulations). However, despite the beneficial effects of millet consumption, the per capita consumption of these millet in India decreased from 32.9 kg in 1962 to 4.2 kg in 2010 (Kane-Potaka *et al*., 2021). Therefore, there is a need to increase millet consumption either directly or indirectly by incorporating in foods. Functional foods with more consumer preference include baby foods, dairy foods, confectionery, ready meals, snacks, meat products, spreads, and beverages. Among these, beverages are the preferable functional food category because of many reasons such as (i) convenience and possibility to meet consumer demands for container contents, size, shape, and appearance; (ii) ease of distribution and better storage for refrigerated and shelf-stable products; (iii) great opportunity to incorporate desirable nutrients and bioactive compounds (Sanguansri and Augustin, 2010; Wootton-Beard and Ryan 2011). Because of this, millet flour incorporation was tried in beverages, especially fruit beverages because traditionally millet flour has been used to prepare malt beverage as a weaning food or porridge. The current consumers demand healthy beverages with new flavours. Moreover, consuming fruits and its products has also been proven beneficial for health. The combination of fruits with millet will provide a unique taste to the consumers in addition to nutrients. Therefore, millet flour was included in the preparation of mango and pineapple RTS (ready-to-serve) beverages. The incorporation of millet flour imparted unique flavour in both mango and pineapple RTS beverages. As a result, both the fruit beverages were accepted by the consumers. Nutritionally, millet flour incorporated beverages showed higher phenols, antioxidant activity and amino acids than control samples. However, it was found that millet flour can be incorporated only at a lower percentage.

Foxtail millet flour incorporated mango RTS beverage

Foxtail millet flour incorporated pineapple RTS beverage

CONCLUSION

Development of new and innovative processed products from millet along with fruits, vegetables and other foods with acceptable sensory quality and high nutritional value is necessary. This would increase the intake of millet by consumers of different age groups without compromising the taste. In addition, it provides the required nutrients to the consumers.

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Recent Approaches Used in Crop Residue Management Based on Rice-W Heat Cropping Systems in Indo-Gangatic Plain

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ABSTRACT

Crop residue management is critical to sustainable agriculture, particularly in rice-wheat cropping systems. In the Indo-Gangetic Plain, which spans India, Pakistan, and Bangladesh, the effective management of crop residues has gained significant attention due to its impact on soil health, the environment, and farm productivity. This review aims to summarize recent approaches and strategies adopted in the region for crop residue management in rice-wheat cropping systems.

INTRODUCTION

Crop residue management plays a crucial role in organic matter addition, enhancing soil moisture retention, infiltration, aeration, and improving the tilth of the soil while protecting it from seasonal wind and rain erosion. Other possible benefits of practicing crop residue management can be- decrement in soil erosion, sedimentation, and pollution from dissolved compounds adhered to the sediments. After the first green revolution, food grain production increased from 50.82 to 310 million metric tons to feed the growing population. The output of straw has increased correspondingly with the growth in grain production. India currently produces 501.73 million tonnes of crop leftovers. More than 60 MT of crop residue is produced in Uttar Pradesh, with Maharashtra and Punjab coming in second and third. Cereals provide the most leftovers (352 MT) among the different crops, followed by fibers (66 MT), oilseeds (29 MT), pulses (13 MT), and sugarcane (12 MT). The seventy percent of the agricultural wastes comes from cereal crops (rice, wheat, maize, and millet), with rice accounting for 34% and crop residues in sugarcane accounts to two percent generated by the top and leaves. In recent years, due to the significant generation of large quantities of crop residues, various approaches and technologies have been developed and implemented efficiently to manage them in the rice-wheat-based cropping systems of the Indo-Gangetic plain. Here are some of the recent strategies employed for crop residue management in this region.

REASON FOR CROP RESIDUE BURNING

- In the olden days Indian farmers used to keep cattle in their sheds, and crop residues particularly paddy, maize, and jowar residues, were utilized as cattle feed. However, over time, farmers started neglecting animal husbandry due to shortages of labor and mechanization.
- Time gap between the *kharif* and *rabi* seasons is too short to allow the residues to decompose *in situ* in the field.
- Sowing of subsequent crops with small-sized seeds will be difficult.
- If crop residue is incorporated, it may result in the yellowing of subsequent crops (nitrogen deficiency).
- Residue burning was adopted to suppress soil-borne pests and diseases.
- Lack of awareness on soil health, quality, nutritional benefits of incorporation, and environmental hazard.
- Lack of farm machinery to efficiently recycle and manage crop residues *in situ.*
- Inadequate policy supports/incentives for crop residue recycling from the government.

NEGATIVE IMPACTS OF RESIDUE BURNING

Soil is a bin of nutrients that supports crop growth. It is crucial to return back these nutrients to the soil. However, the practice of burning crop residues results in several adverse consequences and disruptances to this bin of nutrients by the following ways:

LOSS OF NUTRIENTS: Burning one tonne of rice straw accounts for the loss of 5.5 kg nitrogen, 2.3 kg phosphorus, 25 kg potassium, and 1.2 kg sulphur (NPMCR, 2014). Burning one tone of cotton stalks accounts for the loss of 6.2 kg Nitrogen, 0.8 kg phosphorus, 6.1 kg potassium and 1.5 kg of sulphur besides, organic carbon (Ramanjanelu et al., 2021).

IMPACT ON SOIL PROPERTIES: Crop residue burning has the potential to degrade soil physical, chemical, and biological properties of the soil. The heat from burning residues elevates soil temperature resulting in the death of beneficial soil organisms. Microbial biomass carbon and nitrogen showed a decline of 27.2% and 40.9 %, respectively under rice straw burning over incorporation (Naresh, 2013). The soil nutrient status especially available N was affected more significantly as compared to other nutrients.

EMISSION OF GREENHOUSE AND OTHER GASES: Burning of crop residues emits Green House Gases (GHGs), other aerosols, and hydrocarbons which contribute to global warming. It is estimated that burning one tone of paddy straw could release 60 kg of carbon monoxide, 1460 kg of carbon dioxide, 2 kg sulphur oxides, and 3kg of particulate matter (Bimbraw, 2019), which are responsible for health hazards, loss of biodiversity in agricultural lands, and the deterioration of soil fertility.

THE NUTRIENT POTENTIAL OF CROP RESIDUES: Applied nutrients/ fertilizers to the soil are absorbed by the plants and assimilated into the tissues. Some nutrients will translocate into grains, while the remaining are present in other plant parts such as stubbles, straw, and roots. Therefore, crop residues serve as a potential source of nutrients (Table 1) when incorporated or decomposed into the soil. It is estimated that an average of 30–35% of applied N and P and 70– 80% of K, accumulate in the crop residues of food crops. Conversely, crop residues contain around 40% carbon (on dry weight basis), which can improve the organic matter content in the soil when incorporated. Carbon-enriched crop residue acts as a food source for soil microorganisms and fauna, and as a result 'nurtures' the nutrient cycling. Soil organic matter is indispensable for improving soil conditions congenial for plant growth, and helps in attaining sustainability in crop yields.

Table 1: Nutrient concentration of different crop residues

Crop	N (%)	P_2O_5 (%)	K_2O (%)	Total nutrient	Kg nutrient per ton residue
Rice	0.61	0.18	1.38	2.17	21.7
Sorghum	0.52	0.23	1.34	2.09	20.9
Maize	0.52	0.18	1.35	2.05	20.5
Pulses	1.29	0.36	1.64	3.29	32.9
Oil seed	0.80	0.21	0.93	1.94	19.4
Ground nut	1.60	0.23	1.37	3.20	32.0
Sugarcane	0.40	0.18	1.28	1.86	18.6

Bhattacharjya et al., 2019

RECENT APPROACHES TO CROP RESIDUE MANAGEMENT

- *CONSERVATION AGRICULTURE:* Conservation agriculture practices, such as zero tillage or minimum tillage, are being increasingly adopted in the Indo-Gangetic plain. These practices involve leaving crop residues on the field and directly sowing the next crop into the residues. By minimizing soil disturbance, conservation agriculture helps in retaining crop residues on the soil surface, thereby improving soil health, reducing soil erosion, and enhancing water retention.
- *CROP RESIDUE RECYCLING:* Crop residues, particularly those from the previous rice crop, can be effectively recycled by incorporating them into the soil using various methods. For instance, farmers are using machinery such as **Happy Seeders or turbo happy seeders**, which cut and lift the rice stubble, enabling direct sowing of wheat seed into the field without the necessity of burning or removing

the residue. This practice not only helps in managing crop residues but also contributes to the conservation of soil organic matter.

- *BIOENERGY PRODUCTION:* Another approach is the utilization of crop residues for bioenergy production. Instead of burning the residues, they can be converted into valuable sources of energy, such as biogas or biofuels. This approach not only provides an alternative energy source but also helps in reducing greenhouse gas emissions resulting from open residue burning.
- *AWARENESS AND TRAINING PROGRAMS:* Awareness and training programs are being conducted to educate farmers about the harmful effects of residue burning and the importance of proper residue management. These programs aim to promote alternative practices and technologies for residue management, emphasizing the benefits of retaining residues on the field for soil health and long-term sustainability.
- *FEED FOR LIVESTOCK:* Jowar stalks, maize, and straw from paddy are commonly fed to cattle. According to Goswami et al. (2020), paddy straw may be a poor source of proteins. However, farmers in India still use straw material as feed. In addition to providing the necessary nutrients, storing the straw as silage and hay will provide the cattle with nutrition and effectively utilize crop residues.
- *SURFACE RETENTION AS MULCH:* Using crop residue as soil mulch is a recommended practice for rainfed and irrigated dry crops. Mulching with crop residue requires transfer of straw/ biomass off the field before land preparation and sowing and subsequently returned by making the stalks into appropriate size. Mulching helps to conserve water and improves nutrient use efficiency.
- *PACKAGING FOR TRANSPORT:* In India's urban areas, paddy straw is a popular low-cost packaging material, particularly for packing furniture and fruits.
- *COMPOSTING:* The natural process of organic material being broken down by microorganisms in a controlled environment is called composting. The market offers a wide variety of microbial consortia, including the PJTSAU consortia, Pusa decomposer, and waste decomposer. These bacteria accelerate the breakdown process and turn crop debris or organic matter into compost. Crop wastes that have partially decomposed can be utilized as a basic material for vermicomposting. Composting with crop residues enhances soil nutrient levels and boosts the condition of soil health.
- *BIOCHAR:* A highly porous, fine-grained material with a carbon-dominant composition that is rich in both organic and inorganic paramagnetic centers and has a substantial surface area with oxygen functional groups and aromatic surfaces is called biochar (Atkinson et al., 2010). Biochar is produced through the pyrolysis of biomass waste. Applying biochar made from crop leftovers to the soil may enhance its physical, chemical, and biological qualities. In calcareous soils, biochar made from cotton

Fig. **-1** Different pictures of crops residue management

seeds and shells, rice husks, and cotton seeds decreased soil bulk density while increasing exchangeable K and water retention capacity at a rate of 90 t ha^{-1}(Liang et al. 2014).

- ***IN-SITU MANAGEMENT WITH MECHANIZATION:*** With the advancement of in agricultural technology, innovative machinery has been developed that proves useful in managing crop residue. The following are the few of its kind:
  - ✓ **Reaper Binder**: This tool is used to harvest crops with smooth stems, such as rice and sesame, bind the stems, and create bundles.
  - ✓ **Baler:** After harvesting paddy with a harvester, straw leftovers are collected and made into bales using a baler. Balling paddy straw makes it easier to transport and store.
  - ✓ **Straw Chopper:** After harvesting paddy or other succulent stem crops, the straw chopper is useful for cutting the straw/ stalks into small pieces for easy mixing into the soil.

- ✓ **Rotary mulcher:** After harvesting paddy or other succulent stem crops, rotary mulcher cuts the straw/ stalks into small pieces and spreads them on the soil as mulch.
- ✓ **Rotavator:** It can be useful for the preparation of land by cutting and incorporating crop stubbles into the soil.
- ✓ **Zero till seed drill:** This tool is useful for sowing seeds in the previous crop stubbles with minimum soil disturbance.
- ✓ **Happy Seeder:** Used for sowing of the crop in standing stubble.

CHALLENGES IN RESIDUE MANAGEMENT

- ➢ Paddy straw contains a high amount of silica (8-14%), which is indigestible and decreases the digestibility of the feed hence supporting poor nutrition to cattle, besides low protein content (2-7% crude protein).
- ➢ Decomposition of crop residue, especially that from fiber and cereal crops, is influenced by factors such as residue quality (C: N and composition), microbial population, and soil environment.
- ➢ Availability of machinery to incorporate the straw into the soil.
- ➢ Limited government policies support crop residue management.
- ➢ Mulching residues requires more labor
- ➢ N immobilization occurs after the incorporation of crop residue which hampers initial plant growth (as the time gap between two crops is short).

CONCLUSION

The residue left behind after grain harvesting by machine was burned to maintain clean land. However, there are numerous ways available for managing agricultural residue, both on and off the field. Using equipment such as straw cutters, rotavators, and happy seeders can improve crop residue management. Incorporating the residues directly into the soil or by creating secondary products (such as compost, biochar, etc.) improves soil's physical, chemical, and biological characteristics, reducing air pollution.

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Organic Farming: Promising Future for Agriculture

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ABSTRACT

Adopting organic farming practices, which restrict or eliminate synthetic pesticides, can reduce pesticide-related risks in the food chain. The principles of organic farming aim to promote holistic and regenerative agricultural practices that prioritize long-term sustainability and the well-being of ecosystems and communities. Organic farming aims to create a holistic and sustainable system that supports healthy ecosystems, minimizes environmental impacts, and produces high-quality organic food. With its focus on soil health, reduced chemical inputs, and conservation of natural resources, organic farming is seen as a promising future for agriculture that can contribute to a more sustainable and resilient food system.

INTRODUCTION

Worldwide, the consumption of pesticides has been rising adequately, heightening the human population and crop production. Pesticides are chemical substances used to control or eliminate pests, including insects, weeds, and fungi, that can harm crops or livestock. While pesticides have been instrumental in increasing agricultural productivity and protecting food supplies, their use can have unintended effects on the food chain and the environment. Pesticides can harm non-target organisms, including beneficial insects, birds, and mammals. The unintended targets may be exposed to pesticides through contaminated food or water sources, leading to direct toxicity and even death. In addition, pesticide residues can persist in crops, even after they have been harvested and processed. When humans consume food containing pesticide residues, there is a potential risk of exposure. While regulatory bodies establish maximum residue limits to ensure food safety, prolonged exposure to low levels of pesticides may still have adverse health effects, especially for vulnerable populations like children and pregnant women. Organic farming is an agricultural approach that emphasizes using natural and sustainable practices while minimizing synthetic inputs such as pesticides, fertilizers, and genetically modified organisms. Organic farming practices prioritize the health of the soil, water, and ecosystems. By avoiding synthetic pesticides and fertilizers, organic farmers minimize soil erosion, reduce water pollution, and protect biodiversity.

Organic farms also promote the use of renewable resources, such as organic fertilizers and crop rotation, which help maintain the long-term productivity and sustainability of the land.

ORGANIC FARMING AND ITS COMPONENTS:

Organic farming is an agricultural approach that emphasizes the use of natural and sustainable practices while minimizing the use of synthetic inputs. It encompasses various components and techniques that work together to promote ecological balance, soil health, and sustainable food production. Here are some key components of organic farming:

1. ***Soil management:*** Organic farming prioritizes soil health and fertility. Practices such as crop rotation, cover cropping, and composting are used to improve soil structure, enhance nutrient content, and promote beneficial soil microorganisms. Organic farmers avoid using synthetic fertilizers and instead rely on natural sources of nutrients, such as compost, manure, and organic amendments.
2. ***Pest and disease management:*** Organic farmers employ various pest and disease management strategies without relying on synthetic pesticides. This includes methods such as biological control (using natural predators and beneficial insects), crop rotation, planting disease-resistant varieties, maintaining biodiversity on the farm, and implementing cultural practices that reduce pest and disease pressures.
3. ***Weed management:*** Organic farming emphasizes weed management techniques that minimize the reliance on synthetic herbicides. Practices like mulching, hand-weeding, crop rotation, and the use of cover crops help control weeds. Organic farmers may also use mechanical methods, such as tractor cultivation or flame weeding, to manage weed populations.
4. ***Genetic modification:*** Organic farming prohibits using genetically modified organisms (GMOs). Organic farmers do not use genetically engineered seeds or employ genetic engineering techniques in their production systems. Instead, they focus on preserving and utilizing traditional and heirloom varieties that are adapted to organic farming practices.
5. ***Livestock management:*** Organic livestock farming follows specific guidelines to ensure the welfare of animals and the production of organic animal products. Organic livestock must have access to the outdoors and be provided with organic feed that does not contain synthetic additives or genetically modified ingredients. Growth hormones and preventive antibiotics are restricted, and organic farmers prioritize practices that promote animal health and natural behaviours.
6. ***Certification and standards:*** Organic farming requires certification to ensure compliance with organic standards. Certification is carried out by authorized bodies that inspect farms and processing

facilities to ensure adherence to organic regulations. Organic certification provides transparency and assurance to consumers that the products they purchase have been produced in accordance with organic standards.

7. ***Market access and consumer demand:*** The organic farming sector has grown significantly due to increasing consumer demand for organic products. Organic farmers benefit from market opportunities and premium prices that organic products often command. This demand has led to increased market access and opportunities for organic farmers to sell their products to consumers seeking organic, environmentally friendly, and sustainable food choices.

Figure 1. Components of Organic farming

PRINCIPLES OF ORGANIC FARMING:

Organic farming is guided by a set of principles that promote sustainable and environmentally friendly agricultural practices. These principles serve as the foundation for organic farming methods and certification standards. While specific guidelines may vary between countries and certification bodies, the core principles of organic farming generally include:

1. ***Soil health and fertility:*** Organic farming strongly emphasizes maintaining and improving the health of the soil. This involves practices such as composting, crop rotation, and using organic fertilizers to enhance soil fertility, structure, and nutrient content. In addition, organic farmers aim to nurture a thriving soil ecosystem with beneficial microorganisms, earthworms, and other soil organisms.
2. ***Biodiversity and ecological balance:*** Organic farming aims to promote biodiversity and preserve the natural balance of ecosystems. Farmers utilize crop rotation, agroforestry, and habitat creation techniques for beneficial organisms to support a diverse range of plants, animals, and insects. In addition, by encouraging natural predators, organic farmers can reduce the need for synthetic pesticides and promote pest control through ecological processes.
3. ***Prohibition of synthetic inputs:*** Organic farming prohibits the use of synthetic pesticides, herbicides, and fertilizers. Instead, organic farmers rely on natural pest control methods, such as biological control, crop rotation, and the use of organic-approved pest management products. Organic farmers also avoid the use of genetically modified organisms (GMOs) and genetically engineered seeds.
4. ***Animal welfare:*** Organic farming recognizes animal welfare's importance and promotes ethical livestock treatment. Organic livestock must have access to the outdoors and be provided with suitable living conditions, including adequate space, natural lighting, and the opportunity to engage in natural behaviours. Growth hormones and preventive antibiotics are restricted in organic animal production.
5. ***Avoidance of synthetic additives and processing aids:*** Organic food processing and production standards prohibit the use of synthetic additives, preservatives, and processing aids. Organic processed foods may only contain natural substances and approved organic ingredients. Organic farmers and processors follow strict guidelines to maintain their products' integrity and organic status throughout the production chain.
6. ***Transparency and certification:*** Organic farming requires transparency and certification to ensure compliance with organic standards. Organic farmers and processors must undergo rigorous inspections and certification processes by authorized bodies. Certification ensures that organic products meet defined organic standards and allows consumers to make informed choices when purchasing organic products.

Why is Organic farming a promising future for agriculture?

1. ***Environmental sustainability:*** Organic farming practices prioritize the health of the soil, water, and ecosystems. By avoiding the use of synthetic pesticides and fertilizers, organic farmers reduce the risk of water pollution, soil degradation, and biodiversity loss. Organic farming promotes the use of renewable resources, such as organic fertilizers and cover crops, and emphasizes the conservation of natural habitats and biodiversity. This approach helps to mitigate climate change, protect natural resources, and preserve ecosystems for future generations.
2. ***Soil health and long-term productivity:*** Organic farming builds and maintains healthy soils. Organic farmers enhance soil fertility, structure, and microbial activity through crop rotation, composting, and organic amendments. As a result, healthy soils have improved water-holding capacity, nutrient availability, and overall productivity. In addition, organic farming methods help preserve soil fertility in the long term, reducing the need for synthetic inputs and promoting sustainable agriculture.
3. ***Reduced chemical exposure:*** Organic farming avoids or minimizes the use of synthetic pesticides, herbicides, and fertilizers. This reduces chemical exposure for farmers, farm workers, and consumers. Organic farming reduces the risks associated with toxic chemicals by relying on natural pest control methods, such as biological control and crop rotation. Organic food generally has lower pesticide residues than conventionally grown food, which can contribute to improved human health outcomes.
4. ***Healthier and more nutritious food:*** While the nutritional differences between organic and conventionally grown food are still a subject of debate, some studies suggest that organic crops may have higher levels of certain nutrients, such as vitamins, minerals, and antioxidants. Organic farming practices that prioritize soil health and biodiversity can contribute to better crop nutrient content. Additionally, organic farming avoids the use of synthetic additives, preservatives, and processing aids in organic processed foods, providing consumers with more natural and minimally processed options.
5. ***Market demand and economic opportunities:*** There is a growing consumer demand for organic products, driven by concerns for health, sustainability, and environmental impact. Organic farming offers opportunities for farmers to tap into this market and potentially command premium prices for their products. The demand for organic food continues to rise, and the organic sector offers economic opportunities and market access for farmers and entrepreneurs.

6. ***Resilience and adaptability:*** Organic farming methods often emphasize diversification, crop rotation, and the use of locally adapted varieties. These practices enhance the resilience and adaptability of farming systems to climate change and other environmental challenges. Organic farmers are often more attuned to their farms' natural processes and cycles, allowing them to make informed decisions and adapt their practices accordingly.

BENEFITS OF ORGANIC FARMING:

Some of the benefits associated with organic farming are:

1. ***Environmental sustainability:*** Organic farming practices prioritize the health of the soil, water, and ecosystems. By avoiding synthetic pesticides and fertilizers, organic farmers minimize soil erosion, reduce water pollution, and protect biodiversity. Organic farms also promote the use of renewable resources, such as organic fertilizers and crop rotation, which help maintain the long-term productivity and sustainability of the land.
2. ***Improved soil health:*** Organic farming focuses on building and maintaining healthy soils. Organic farmers enhance soil fertility, structure, and microbial activity by using techniques like composting, cover cropping, and crop rotation. Healthy soils retain more water, promote better nutrient cycling, and provide a favourable environment for plant growth. This can result in increased yields and improved long-term productivity.
3. ***Enhanced biodiversity:*** Organic farms support biodiversity by creating habitats for beneficial insects, birds, and other wildlife. They avoid the use of synthetic pesticides that can harm non-target organisms, such as pollinators and natural predators of pests. Organic farming practices, such as maintaining hedgerows and preserving natural habitats, contribute to the conservation of native species and the overall ecological balance.
4. ***Reduced chemical exposure:*** Organic farming reduces chemical exposure for farmers, farm workers, and consumers. By avoiding the use of synthetic pesticides and fertilizers, organic farmers minimize the risks associated with toxic chemicals. Studies have shown that organic food generally has lower pesticide residues than conventionally grown food, which can contribute to improved human health outcomes.
5. ***Nutritional quality:*** While the nutritional differences between organic and conventionally grown food are still a subject of debate, some studies suggest that organic crops may have higher levels of certain nutrients, such as vitamins, minerals, and antioxidants. Organic farming practices that focus on soil health and biodiversity can contribute to better nutrient content in crops.

6. ***Consumer demand and market opportunities:*** There is a growing consumer demand for organic products, driven by concerns for health, sustainability, and environmental impact. Organic farmers can benefit from market opportunities and potentially command premium prices for their products. Organic certification provides transparency and reassurance to consumers, leading to increased market access and potential economic benefits for farmers.

CONCLUSION

Adopting organic farming practices, which restrict or eliminate synthetic pesticides, can reduce pesticide-related risks in the food chain. The principles of organic farming aim to promote holistic and regenerative agricultural practices that prioritize long-term sustainability and the well-being of ecosystems and communities. Organic farming aims to create a holistic and sustainable system that supports healthy ecosystems, minimizes environmental impacts, and produces high-quality organic food. Organic farming offers a holistic and sustainable approach to agriculture that aligns with the increasing consumer demand for healthy, environmentally friendly, and ethically produced food. With its focus on soil health, reduced chemical inputs, and conservation of natural resources, organic farming is seen as a promising future for agriculture that can contribute to a more sustainable and resilient food system.

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Carbon Credits: A Key Tool In Climate Change Mitigation, Strategies And Approach For A Sustainable Future

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ABSTRACT

Carbon credits, also known as carbon offsets, play a crucial role in climate change mitigation by providing a mechanism to compensate for greenhouse gas emissions and promote sustainability. They offer numerous benefits, including the adoption of cleaner technologies, investment in sustainable projects, and transition to a low-carbon economy. The prospects for carbon credits are promising, with increasing global awareness of climate change driving the demand for emissions offsets. However, challenges such as ensuring environmental integrity and strengthening monitoring systems must be addressed. Nevertheless, carbon credits hold immense potential in facilitating emissions reductions and contributing to a sustainable future.

INTRODUCTION

Carbon credits, also known as carbon offsets or emission reduction credits, are a unit of measurement that represents the reduction, avoidance, or removal of greenhouse gas (GHG) emissions (Wara & Victor, 2008). Each carbon credit typically equals one metric ton of carbon dioxide equivalent (CO_2e). Carbon credits are used to incentivize and support activities that mitigate climate change by reducing GHG emissions. The concept of carbon credits is based on the principle that not all emissions can be eliminated immediately and that emission reductions can be achieved through various means. By assigning a financial value to carbon reductions, carbon credits create a market mechanism where entities can buy and sell credits to compensate for their emissions. The concept encourages emission reduction efforts beyond legally required and provides economic incentives for sustainable practices and investments.

HISTORY OF CARBON CREDITS

The concept of carbon credits emerged as a response to the need for international cooperation in reducing GHG emissions and addressing climate change (Kolk *et al*., 2008). Here is a brief history of carbon credits:

1. 1997: Kyoto Protocol - The Kyoto Protocol, an international treaty to combat climate change, introduced market-based mechanisms to reduce emissions. It established the Clean Development Mechanism (CDM) and Joint Implementation (JI) as mechanisms for generating carbon credits (Matsuo, 2003).
2. Clean Development Mechanism (CDM) - The CDM allowed developed countries to invest in emission reduction projects in developing countries and earn Certified Emission Reductions (CERs) for each ton of CO2e reduced. CERs could be used by developed countries to meet their emission reduction targets (Carr & Rosembuj, 2008).
3. Emission Trading Systems - In the early 2000s, various emission trading systems were established, such as the European Union Emission Trading Scheme (EU ETS). These systems allocated emission allowances to industries, creating a market for trading carbon credits.
4. Voluntary Carbon Markets - Alongside compliance markets, voluntary carbon markets emerged to facilitate carbon offsetting beyond regulatory requirements. These markets allow businesses and individuals to voluntarily purchase carbon credits to offset their emissions and demonstrate environmental responsibility.
5. Carbon Standards and Certification - Several standards and certification bodies were established to ensure the credibility and integrity of carbon credits. These include the Verified Carbon Standard (VCS), Gold Standard, American Carbon Registry (ACR), and Climate Action Reserve (CAR), among others.
6. Paris Agreement - The Paris Agreement, adopted in 2015, encouraged market-based approaches to support emission reductions. The agreement recognizes the importance of carbon markets and calls for enhancing and coordinating international cooperation in this regard.
7. Today, carbon credits play a significant role in both compliance and voluntary markets, enabling businesses, governments, and individuals to take climate action, achieve emission reduction targets, and support sustainable projects worldwide.

THE ULTIMATE GOAL OF CARBON CREDITS

The ultimate goal of carbon credits is to mitigate climate change by reducing greenhouse gas (GHG) emissions and promoting sustainable practices (Ruddell *et al.*, 2007). Carbon credits aim to achieve the following:

1. Emission Reduction: The primary goal of carbon credits is to incentivize and support activities that reduce GHG emissions. By assigning a financial value to carbon reductions, carbon credits encourage entities to adopt cleaner technologies, improve energy efficiency, implement renewable energy projects, and engage in other emission reduction initiatives.
2. Climate Change Mitigation: Carbon credits contribute to global efforts to mitigate climate change by helping to achieve emission reduction targets set by international agreements, such as the Paris Agreement. They provide a mechanism for countries, industries, and organizations to offset their emissions and work towards a low-carbon economy.
3. Transition to a Sustainable Future: Carbon credits drive the transition to a sustainable future by promoting investments in renewable energy, energy efficiency, sustainable forestry, and other environmentally friendly projects. They encourage developing and deploying technologies and practices that reduce dependence on fossil fuels and promote sustainable development.
4. Economic and Social Co-benefits: Carbon credits offer economic and social co-benefits alongside emission reductions. They can generate revenue for governments and organizations by selling credits, which can be reinvested in climate-related initiatives. Carbon credit projects can also create job opportunities, support local communities, and contribute to sustainable development goals.
5. Conservation and Restoration: Carbon credits support conservation and restoration efforts by incentivizing projects that protect and restore forests, wetlands, and other ecosystems. These projects contribute to biodiversity conservation, water resource management, and the preservation of natural habitats, thereby enhancing ecosystem services.
6. Global Cooperation: Carbon credits promote global cooperation and collaboration in addressing climate change. They provide a framework for countries and entities to collaborate, share knowledge and resources, and support emission reduction projects across borders. In addition, carbon credit mechanisms encourage developed countries to support emission reduction efforts in developing countries through financial and technical assistance.
7. The ultimate goal of carbon credits is to facilitate a transition to a low-carbon economy, reduce the impact of human activities on the climate system, and create a sustainable and resilient future for current and future generations.

THE ALLOCATION OF CARBON CREDITS

The allocation of carbon credits refers to the process of distributing or assigning carbon credits to entities or projects based on specific criteria and methodologies. The allocation can occur through various mechanisms, depending on the type of carbon market and the regulatory framework in place. Here are some common methods of allocating carbon credits:

1. Emission Trading Systems (ETS): In cap-and-trade systems, carbon credits are initially allocated or auctioned by the government to covered entities, such as power plants, factories, or airlines. The allocation is often based on historical emissions, sector-specific benchmarks, or a combination of factors. As the cap on emissions is gradually reduced over time, the allocation is adjusted to align with emission reduction targets.
2. Clean Development Mechanism (CDM): Under the CDM, carbon credits, known as Certified Emission Reductions (CERs), are generated from emission reduction projects in developing countries. These projects are verified and registered under the United Nations Framework Convention on Climate Change (UNFCCC). The allocation of CERs is based on the emission reductions achieved by the project, following approved methodologies and guidelines.
3. Voluntary Carbon Markets: Carbon credits are often allocated to projects that go beyond regulatory requirements and voluntarily reduce emissions or remove carbon from the atmosphere. The allocation may be based on the verified emission reductions achieved by the project, which are independently assessed and certified by recognized standards and certification bodies.
4. Offset Projects: Offset projects, such as reforestation, renewable energy, or energy efficiency initiatives, can generate carbon credits based on the emission reductions or removals they achieve. Depending on the agreement or contractual arrangements, these credits can be allocated to the project developers or entities that finance or support the project.
5. Auctions and Market Mechanisms: Some carbon markets use auctions to allocate carbon credits. Auctions provide a transparent and competitive process for entities to acquire credits. The credits are typically sold to the highest bidder or distributed based on predetermined rules. Auctions can promote price discovery and efficiency in the carbon market.

TRADING CARBON CREDITS

Trading carbon credits refers to the buying and selling of carbon credits in the carbon market. It involves the transfer of ownership of carbon credits between entities with the aim of meeting emission reduction obligations, achieving sustainability goals, or voluntarily offsetting emissions. Here are key aspects of trading carbon credits:

1. Marketplaces and Exchanges: Carbon credits can be traded on specialized platforms or exchanges that facilitate the buying and selling of credits. These marketplaces provide a centralized platform where buyers and sellers can interact, negotiate prices, and execute transactions.
2. Bilateral Transactions: Carbon credits can be traded through bilateral agreements between two parties, such as companies or organizations. These agreements may be structured as direct transactions, contracts, or purchase agreements.
3. Spot Market: In spot trading, carbon credits are bought and sold for immediate delivery and settlement, usually at the prevailing market price. Spot markets allow for quick transactions, enabling entities to meet their immediate carbon offset needs.
4. Futures and Options: Some carbon markets offer futures and options contracts, allowing entities to trade carbon credits for future delivery. Futures contracts specify the quantity and price of carbon credits to be delivered at a predetermined future date, while options contracts give the holder the right but not the obligation to buy or sell carbon credits at a specified price within a specified timeframe.
5. Compliance and Voluntary Markets: Trading occurs between compliance markets and voluntary markets. Government authorities regulate compliance markets and require entities to comply with emission reduction targets or obligations. On the other hand, voluntary markets provide a platform for entities to offset their emissions beyond regulatory requirements voluntarily.
6. Price Determination: The price of carbon credits is determined by market forces, including supply and demand dynamics, regulatory policies, market sentiment, and overall market conditions. The price can vary over time, reflecting changes in emission reduction targets, policy developments, and market trends.
7. Verification and Certification: Carbon credits traded in reputable markets must often undergo verification and certification processes. These processes ensure the validity, accuracy, and transparency of the emission reductions associated with the credits, providing confidence to buyers and ensuring environmental integrity.
8. International Transactions: Carbon credits can be traded internationally, allowing entities in different countries to participate in emission reduction projects or offsetting initiatives. International transactions can foster global cooperation and support emission reduction efforts where they are most cost-effective.
9. Trading carbon credits plays a vital role in driving emission reductions, facilitating investments in low-carbon technologies and projects, and creating economic incentives for sustainable practices. It allows entities to achieve their emission reduction goals, comply with regulations, and contribute to global climate change mitigation efforts.

TYPES OF CARBON CREDITS

There are several types of carbon credits, each representing a specific type of emission reduction or removal activity. Here are the common types of carbon credits:

1. Certified Emission Reductions (CERs): CERs are generated under the Clean Development Mechanism (CDM) of the Kyoto Protocol. These credits represent emission reductions achieved by projects in developing countries that have been registered and verified by the United Nations Framework Convention on Climate Change (UNFCCC). CERs can be used by industrialized countries to meet their emission reduction targets.
2. Verified Emission Reductions (VERs): VERs, also known as Voluntary Emission Reductions or Voluntary Carbon Units, are generated through projects in voluntary carbon markets. These projects voluntarily reduce or remove greenhouse gas emissions beyond what is legally required. VERs are typically verified and certified by recognized standards and can be used by companies, organizations, or individuals to offset their emissions voluntarily.
3. Emission Reduction Units (ERUs): ERUs are generated under the Joint Implementation (JI) mechanism of the Kyoto Protocol. Like CERs, ERUs represent emission reductions achieved by projects, but these projects are implemented in developed countries. ERUs can be used by countries to meet their emission reduction targets under the Kyoto Protocol.
4. Removal Units (RMUs): RMUs represent carbon dioxide removal from the atmosphere through carbon sequestration projects, such as afforestation or reforestation initiatives. These projects enhance carbon sinks by planting trees or restoring forests, removing carbon dioxide from the atmosphere. RMUs can be used to offset emissions or traded in carbon markets.
5. Renewable Energy Certificates (RECs): RECs, also known as Renewable Energy Credits or Green Power Credits, represent the generation of clean and renewable energy from sources like wind, solar, hydro, or biomass. RECs certify that a specific amount of electricity was produced from renewable sources. Entities can purchase these credits to support renewable energy generation and offset their fossil fuel-based electricity consumption.
6. Carbon Removal Credits (CRCs): CRCs directly remove carbon dioxide from the atmosphere using carbon capture and storage (CCS) technologies or other negative emission technologies. These credits reflect the net carbon dioxide removal, contributing to overall emission reductions and climate change mitigation efforts.
7. Blue Carbon Credits: Blue carbon credits are associated with the conservation, restoration, or sustainable management of coastal and marine ecosystems, such as mangroves, seagrasses, and salt

marshes. These ecosystems are highly efficient in storing carbon and can generate credits based on the carbon sequestration they provide.

BENEFITS OF CARBON CREDITS

Carbon credits offer several benefits that contribute to climate change mitigation, environmental conservation, and sustainable development (Bustamante *et al*., 2014). Here are some key benefits of carbon credits:

1. Emission Reduction and Climate Change Mitigation: Carbon credits incentivize and support projects that reduce greenhouse gas emissions. By providing a financial value for emission reductions, carbon credits encourage the adoption of cleaner technologies, energy efficiency measures, and renewable energy projects. This leads to significant reductions in carbon dioxide and other greenhouse gas emissions, helping to mitigate climate change.
2. Environmental Conservation and Restoration: Many carbon credit projects focus on environmental conservation and restoration efforts. Projects such as reforestation, afforestation, and sustainable land management activities contribute to biodiversity conservation, ecosystem restoration, and the protection of natural habitats. These projects help preserve critical ecosystems, enhance wildlife habitats, and improve water quality and watershed management.
3. Sustainable Development and Co-benefits: Carbon credits often generate co-benefits that promote sustainable development. Projects can provide economic opportunities, create jobs, and support local communities, particularly in developing countries. Carbon credit initiatives may also enhance energy access, improve air and water quality, and enhance resilience to climate change impacts, thereby fostering sustainable and resilient communities.
4. Financial Incentives and Investment Opportunities: Carbon credits provide financial incentives for emission reduction projects. The sale of carbon credits generates revenue that can be reinvested in sustainability initiatives, further promoting the transition to a low-carbon economy. It also attracts investments in renewable energy, energy efficiency, and other clean technologies, driving innovation and supporting the growth of green industries.
5. Corporate Social Responsibility and Reputation: Participation in carbon credit programs allows companies and organizations to demonstrate their commitment to environmental sustainability and climate action. By offsetting their emissions through carbon credits, businesses can enhance their reputation, meet stakeholder expectations, and demonstrate corporate social responsibility. Carbon credits provide a tangible way for entities to take concrete action in addressing their carbon footprint.

6. Access to Carbon Markets and Compliance Flexibility: Carbon credits provide entities with access to carbon markets, allowing them to meet regulatory requirements and emission reduction targets. They offer flexibility in compliance by enabling entities to offset a portion of their emissions through certified projects rather than solely relying on internal emission reduction measures. This flexibility supports a smooth transition to low-carbon practices.
7. International Cooperation and Transfer of Technology: Carbon credits foster international cooperation in addressing climate change. They encourage collaboration between developed and developing countries, facilitating the transfer of environmentally friendly technologies, knowledge sharing, and capacity building. Carbon credit projects can leverage resources and expertise from developed countries to support emission reduction efforts in developing nations.
8. Carbon credits play a vital role in incentivizing emission reductions, promoting sustainable practices, and channelling investments toward low-carbon initiatives. In addition, they provide a mechanism for entities to take responsibility for their carbon footprint while contributing to global climate change mitigation efforts and sustainable development goals.

CONCLUSION

Carbon credits are vital in achieving climate change mitigation goals by incentivizing emissions reductions and promoting sustainability. They offer numerous benefits, including the adoption of cleaner technologies, investment in sustainable projects, and transition to a low-carbon economy. The prospects for carbon credits are promising, with increasing global awareness of climate change driving the demand for emissions offsets. However, challenges such as ensuring environmental integrity and strengthening monitoring systems must be addressed. Nevertheless, carbon credits hold immense potential in facilitating emissions reductions and contributing to a sustainable future.

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