Sustainable Development Goal: Sustainable Management and Use of Natural Resources in Textile and Apparel Industry

Shanthi Radhakrishnan

Abstract The United Nations has envisaged a sustainable development plan for the year 2030 which initiates 17 sustainability development goals (SDGs) with objectives that promote all round development. This forum encourages contributions from all sectors—governments, industrial, civil organizations, public and private sectors—as opportunities for the fulfillment of these goals. The textile and fashion industries have been very popular in the extensive use of natural resources accompanied by waste and waste products that tend to pollute the environment causing hazards to the living organisms in the planet. Businesses and brands in the textile and apparel sector are earnestly working on aligning their production and management on the basis of sustainability, the pinnacle being the sustainability development goals. This chapter deals with the sustainable management and effective use of natural resources (SDG 12—Target 12.2)—water, energy and soil for the development of sustainable textile fibers and certification methodologies for sustainable reporting (SDG 12—Target 12.6). This can be achieved by sound management of chemicals and wastes occurring in the production cycle or life cycle of a product (SDG 12—Target 12.4). Green productivity in sustainable manufacturing calls for improved resource efficiency and waste reductions by implementing a cleaner manufacturing strategy. The specialized long value chain of the textile and fashion industry is poised to address the sustainability challenge to achieve the economic, social and environment development goals.

1 Introduction

In the year 2000, the millennium development goal was initiated on a global scale, with the aim to deal with the humiliation of poverty. The combined efforts of the world helped in accomplishing development and eradicating poverty among the lives of many people, but the program remained unfinished. Efforts to continue the good work of the MDGs were essential giving rise to the post-2015 development agenda

S. Radhakrishnan (✉)
Costume and Apparel Designing, PSGR Krishnammal College for Women, Coimbatore, India

S. S. Muthu (ed.), *Sustainable Approaches in Textiles and Fashion*, Sustainable Textiles: Production, Processing, Manufacturing & Chemistry,
https://doi.org/10.1007/978-981-19-0530-8_8

which has integrated the core essence of sustainability—sustainability development goals (SDGs) [1]. In 2012, the UN Conference on Sustainable Development held in Rio de Janeiro formed the starting point of the Sustainable Development Goals. In September 2015, the UN General Assembly adopted the sustainability development goals—a 15 year agenda till 2030 [2]. With 17 goals and 169 targets, the SDGs are broader in scope and tend to address and eradicate the root causes of poverty leading to development suited to all people around the globe. The new goals are universal and encompass the three dimensions of sustainability—economic development, social inclusion and environmental safety. Powerful focus on implementation is a key factor with the SDGs in terms of resource mobilization, competence building and expertise complemented with institutional organization for data analysis and reporting frame work. The impetus and success of the MDGs have led to the formulation and implementation of the SDGs.

During the SDG Summit in September 2019, world leaders felt that though progress was made in many places, the achievements were not progressing at the required speed or scale to reach the targets by 2030. A Decade of Action was prescribed on three levels [3], namely **global action** for better leadership, additional resources and smart solutions for the SDGs; **local action** which calls for the necessary changes and conversion of policies, financial plans, regulatory and institutional frameworks of governments and local authorities; and **people action** at the grassroots level which includes all stake holders to facilitate and extend their support and enthusiasm to achieve the acceleration for fulfillment of the goals. The Sustainability Development Report showcases the global assessment of the progress of the member countries toward achieving the SDGs and further strengthened by the SDG indicators and the voluntary reviews provided by the nations [4]. The Sustainability Development Report 2021, the seventh edition, unfolds with four ***Chapters*** [5] (Part 1—Increasing the Fiscal Space of Developing countries to achieve the SDGs; Part 2—The SDG Index & Dashboards; Part 3—Policy efforts and Monitoring Frameworks for the SDG; Part 4—Methods Summary & Data Tables); ***Rankings with interactive maps*** [6, 7] of all the 193 UN Member States assessed as overall score and spill overs. The overall score shows the total progress of a country toward achieving all the 17 SDGs. The spill over score shows the positive/negative effects of a country's actions on the other countries' ability to achieve the SDGS. This is assessed over 3 dimensions as impacts in terms of environmental, social and security. A higher score shows more positivity; ***Country Profiles*** [8] track the progress and trends in achieving the SDGs in the member nations; ***Data Explorer*** [9] provides the norms set for each SDG and shows the nations under the each category along with their achievement status from 2010 to 2020. The reports, supplementary materials, SDG indices and databases are all downloadable to readers.

Ensure sustainable consumption and production pattern, SDG 12 [10, 11], promotes efficient management of resources and energy, sustainable infrastructure, access to basic services, green jobs and better quality of life. This goal aims at all round development and reduction of poverty. Currently, awareness of natural resource consumption has increased and efforts have begun to curtail air, water and soil pollution. 'Doing more and better with less' is the focus of SDG 12 and this calls for higher net gains in economic activities when care is taken to reduce use of resources, degradation and pollution along the entire life cycle, thereby bringing in a change in the quality of life. This requires help to the producers to the final consumers through education on sustainable consumption and lifestyle change, provision of information through standards and labels and making it easy for sustainable public procurement.

SDG 12 has 11 targets and 13 indicators as specified by the UN. The targets are the goals and the indicators are the metrics by which the goals are achieved. The targets and the metrics are given in Table 1 [12].

The online data base for the Sustainability Development Report 2021 [13] reveals that the extent of goal achievement for SDG 12 among the 206 entries was 27 (13.23%) denoted by the color green; yellow color denotes 'challenges remain' being 51 (25%); orange for 'significant challenges' being 55 (26.96%); red for 'major challenges' was 53 (25.98%); and gray showing no information being 18 (8.8%). The aim is to slowly remove challenges and move all participating nations into the green color which signifies 'goal achievement'. The indicators used for assessment were municipal solid waste (kg/capita/day), electronic waste (kg/capita), production-based SO2 emissions (kg/capita), SO2 emissions embodied in imports (kg/capita), production-based nitrogen emissions (kg/capita), nitrogen emissions embodied in imports (kg/capita) and non-recycled municipal solid waste (kg/capita/day).

Raw material conservation from natural sources is of primary importance as it results in safeguarding the environment. According to the SDG Report 2020, the Global Material Footprint has increased from 73.2 billion metric tons in 2010 to 85.9 billion metric tons in 2016 (+17.3%) [14]. Biodiversity loss—over 31,000 species are in the extinction list which is 27% more than the species indicated in the IUCN Red list (1–6). Agricultural expansion has caused the decline of forest areas at an alarming level; between 2015 and 2020, each year 10 million hectares of forest areas have been destroyed [15]. The report also mentions that the fossil fuel subsidies have risen from $318 billion to $427 billion being one of the primary contributors to climate change crisis. The COVID-19 crisis has offered opportunities to concentrate on recovery plans to build a sustainable future. This principle has been activated as the report also states that between 2015 and 2017, 79 countries and the European Union have contributed to *sustainable consumption and production* with change in at least one policy [14].

Environmental crimes are destruction of the environment and squandering of natural resources by illegal activities. To quote a few examples [16]:

- The illegal activities in the Amazon Rain forest include clearance of land, illegal logging, wild life mining and trafficking which affect biodiversity and climate change. These activities are accompanied with extensive violence, corruption, human slavery and money laundering.
- In western Guyana, the village of Etheringbang is notable for illegal gold mining conducted under the watch of 'Sindicators', the Columbian ELN and Venezuelan mafias, along with the Venezuelan security forces. All supplies pass through check points where extortion payments are charged at gunpoint.

Table 1 SDG 12 Targets and indicators [12]

Target	Target description	Indicator	Indicator description
12.1	Implement the 10 year framework of programs on SC&PP with all countries taking action by 2030	12.1.1	Number of countries that have a SC&P national action plan
12.2	Achieve sustainable management and efficient use of recourses	12.2.1	Material footprint per capita and per GDP (sum total of material footprint for biomass, fossil fuels, metal and non-metal ores)
12.3	Halve global per capita food waste	12.3.1	Global food loss index (reduce food loss at retail and consumer level; post-harvest losses; along production and supply chains
12.4	Achieve environmentally sound management of chemicals and all waste through international frameworks	12.4.1	Percentage of countries meeting the commitments and obligations within each agreements
		12.4.2	Hazardous waste generated per capita, proportion of hazardous waste treated, type of treatment
12.5	Sustainably reduce waste generation through prevention, reduction, recycling and reuse	12.5.1	National recycling rates, tons of material recycled
12.6	Encourage companies to adopt sustainable practices and reports	12.6.1	Number of companies publishing sustainability reports
12.7	Promote sustainable public procurement practices	12.7.1	Number of companies implementing public procurement practices and action plans
12.8	Promote universal understanding of sustainable lifestyles in harmony with nature	12.8.1	Extent to which sustainable education is mainstreamed (global citizenship and sustainable development education)
12.A	Support the developing countries for scientific and technological capacity for SC&P	12.A.1	Amount of support on research and development for SC&P
12.B	Develop and implement to monitor sustainable development impacts for sustainable tourism	12.B.1	Number of sustainable tourism strategies/policies/action plans with the prescribed evaluation tools
12.C	Rationalize inefficient fossil fuel subsidies that encourage wasteful consumption	12.C.1	Amount of fossil fuel subsidies per GDP in proportion to the total national expenditure on fossil fuels

- The state of Roraima, in Brazil, has no legal mine but has exported 771 kg of gold during the last 3 years. There are about 5000 illegal miners and illegal mining has resulted in elevated mercury poisoning of over 90% of the villagers tested, increase in homicide rates and displacement along the Brazil-Venezuela border.

- Brazil's Amazon has witnessed illegal seizures of both public land and indigenous areas and clearing of forest for cattle pasture. The number of cattle in the Amazon has reached 86 million in 2018 which is 4 times more when compared to 1988.

Illegal mining is one of the main drivers which has accounted for one quarter of the deforestation in the Amazon. The violence against indigenous people increases by about 150% in 2019, while deforestation grew by 25% in the beginning of 2020. It has been reported that about 2,540 violent incidents have been documented targeting environmental defenders which included 406 assassinations [16]. The destruction in the Amazon region has reached the pinnacle and the urgent need of the hour is to undertake efforts to interrupt and dismantle environmental crimes.

It may be noted that SDGs have brought about transformations in many business markets. H&M has brought about a series of changes and targets, namely use of 100% sustainable cotton (organic, recycled or certified by bCI) by 2020; raising the target for collection of used clothes to 25,000 tons per year by 2020; promotion of innovation, e.g., re:newcell; focus on energy efficiency, renewable energy and carbon sinks for absorption of greenhouse gas emissions; fair living wages; vegan leather; foundation 500; recycling blend textiles by hydrothermal process; and so on. These efforts have resulted in the titles 'One of the world's most Ethical Companies' by the Ethisphere Institute, for the seventh time in a row, Freedom House Award for leadership and global supply chain transparency.

The H&M group's sustainability work has been noted by those outside the company. In 2017, the H&M group was named as one of the world's most ethical companies by the Ethisphere Institute—for the seventh year in a row. The group also won the Freedom House Corporate Award for its leadership in advancing global supply chain transparency. The American organization Freedom House gives the award to recognize businesses for their principled policies and strong leadership in the area of human rights. The H&M group was ranked third in the Fashion Transparency Index, which evaluates supply chain transparency among the world's 100 largest fashion companies and also in terms of environmental and social impacts. H&M is also listed in the Dow Jones Sustainability Index—World & Europe, FTSE4Good and also in the Corporate Knights—Global 100 Most Sustainable Corporations in the World [17].

The above is an example, but there are many institutions and companies which are striving hard and relentlessly to fulfill the SDGs targets and work toward sustainability.

2 Natural Resources—Use and Management

2.1 Use of Natural Resources

Any material from the planet Earth that is used to meet the needs and support humans can be considered as a *natural resource*. Natural resources are used to make food (plants and animals), fuel (coal, natural gas and oil) and raw materials (metals, stone, wood and sand) for the making products. Some of the results of extracting and using virgin resources from nature may cause pollution of land, water or air, disturbance/extermination of ecosystems and a reduction in biodiversity, which deals with the variety of plant and animal life in the world. The Sustainable Europe Research Institute (SERI) report, 2009, states that the annual natural resource extraction was 60 billion tons of raw material, which is around 50% more than what was extracted 30 years ago; further, the prediction is that the extraction of natural resources could increase to 100 billion tons by 2030. The report also highlights the consumption behavior of rich versus poor countries of the world. Rich countries consume 10 times more natural resources than the poor countries, e.g., North America (90kg resources/day) and Europe (45 kg resources/day), while Africa consumes 10 kg resources per day [18]. Case studies also reveal the negative environmental and social impacts of extraction in developing and emerging countries, namely oil extraction in Nigeria, copper mining in Peru and palm oil production in Indonesia and Malaysia. The challenge facing the world is to ensure a high quality of life for the current global population and for the increasing population of the future, without surpassing the environmental resource capacity of the planet.

Let's see what happens when we overuse resources. The most common greenhouse gas is carbon dioxide emitted while burning coal, oil and natural gas. The solar heat is absorbed and retained by the greenhouse gases leading to increase in the global temperature of the atmosphere near the Earth's surface. This condition over time can cause serious dangers like flooding, drought and disease. The current commitments will lead to around 3°C global warming by the end of the century which would be fatal and catastrophic to small islands and coastal areas. The climate change drama has unfolded by way of Caribbean storms, wild fires and droughts in Africa [19].

Overuse and extraction of natural resources can ring alarm bells within ecosystems. Any biological community with organisms that live and interact with each other in the same physical environment is termed as an ecosystem. While studying nature, the ecosystem is the most basic and fundamental unit. It is made up of two components, namely the *biotope or abiotic constituent,* which deals with a physical environment with specific physical characteristics like climate, temperature, pH, nutrient composition, humidity, etc., and the *biocenosis/biotic constituent* consisting of a set of living organisms like animals, plants, microorganisms, which are continuously interacting and interdependent with each other [20]. This relationship can extend to any scale like any living organisms/plants with lakes and water bodies; mountains and forests with Mother Earth. Preservation of ecosystems is of primary importance as humans are dependent on the ecosystems for survival. For cereals, vegetables and agriculture to take place, natural processes like pollination, soil characteristics, temperature and humidity are important. If these conditions are drastically changed, then the results may become harsh and irreversible. Since all the living organisms are dependent on the environment and ecosystem, a balance has to be maintained. Techniques like agroforestry, permaculture and regenerative agriculture are built on these concepts to maintain and build a robust ecosystem.

Ecosystems provide water, food (cattle and sea food), products (pharma, biochemicals and industrial products) and energy (sunlight, biomass and hydropower) as in Fig. 1. The most important regulating services offered by ecosystems are climate regulation where oceans, trees and soil facilitate the absorption of carbon and storage; the microbial process occurring in the soil–waste decomposition; contribution by bees and other insects to help crop pollination and reproduction; regulatory processes for water and air purification and control of pests and diseases. Supporting and habitat services include primary reproduction, nutrient and seed dispersal. Cultural services that touch the inner consciousness of human beings are inspiration for creativity, entertainment and spirituality; ambience for introspection, silence and reflection; feeling of goodness and happiness; recreation, adventure and ecotourism; scientific innovation based on the principles of nature-biomimicry.

To explain the importance of the ecosystem and its preservation, we have the story of how humans had affected the ecosystem of the US Yellowstone National Park. As a predator control measure, the US Biological Survey killed the wolves and other species resulting in the disappearance of the wolf population which lead to a number of chain reactions—Tropic Cascade. It is an ecological phenomenon which starts at the top of the food chain and reaches down to the bottom. When the wolves vanished, the deer population grew tremendously grazing the vegetation to nothing. After 70 years, the wolves were introduced into the park in 1995. The wolves not only kill animals but also give life to many other species. They killed some of the deer and radically changed the behavior of the deer. The deer started avoiding the valleys and the gorges, the areas where they could be spotted and hunted easily; once the grazing diminished, these places started to regenerate—the height of trees became 5 times more in 6 years and the barren lands gave rise to willow, cottonwood and aspen trees beckoning the birds and the beavers which feed on trees. The beavers created opportunities for other species like otters, muskrats, fish, reptiles and amphibians. The wolves killed coyotes increasing the number of mice and rabbits leading to the

Fig. 1 Services offered by ecosystems

arrival of more eagles, foxes, hawks, badgers and weasels. The ravens, bald eagles and bears fed on the carcass left by the wolves. The berries from the shrubs and the abundant food led to the population increase of the bears. Further, there was a change noticed in the behavior of the rivers. Lesser erosion caused lesser meandering and narrowing of channels forming numerous pools and rifle sections, creating a haven for wildlife habitat. The regenerative forests on the stabilized banks helped in marking the courses of the rivers; the vegetation in the valley and gorges flourished resulting in lesser soil erosion. On the whole, the wolves transformed the ecosystem of the Yellowstone National Park and its physical geography. The rivers changed in response to the wolves [21], the efficient ecosystem engineers. There are similar stories where human activities have caused severe disruption to the ecosystems.

Diminishing the biodiversity is another result of greedy extraction of the natural resources for industrialization. Biodiversity is built on three main concepts, namely ecosystem, species diversity and genetic diversity. When these three parameters are strong and interactive, the biodiversity will be resilient. The components of a biodiverse system ensure the health of the ecosystem and its inhabitants by processes like purification of water and air, control of diseases and pests, support pollination and enhance fertility of soil and storage of carbon. Biodiversity is the core which makes a place habitable, healthy and liveable. Currently, ecosystems are encroached and altered by human activity changing and impacting the phase, characteristics, specificities and functions of an environment.

Genetic diversity is the variety of genes that exist among living organisms. There are differences in genes, and their expression is also different among species and within different species. The variance in genes gives rise to a wide range of life forms and variation in physical and biological characteristics based on the interaction with the environment. The term ‘phenotype’ is the observable physical characteristics of an organism like appearance, development and behavior. Phenotype is determined by the type of genes and the environment which influences their development [22]. Even though the genes are identical, e.g., identical twins, they may express dissimilar phenotypes based on the environmental influence. Some of the phenotypic characteristics are height, wing length and hair color, while there are others that can be measured in the laboratory, such as hormone levels and blood cells. Hence, the quality and properties of the natural resources are dependent on the genetic set up and the environment.

Species diversity is the variety of living species on Earth and is divided into groups like insects, animals, plants, fungi…. The diversity may be of two types: intraspecies diversity is the genetic variation of organisms of the same species, e.g., hair color, skin color and eye color variations in human beings, and interspecies diversity is the variety of living species in terms of number, nature and importance; namely, human species (7.7 billion) have greater diversity than African elephants (reaching extinction). Species richness is the number of species in an ecosystem, e.g., tropical areas which have an abundant variety of species. Species evenness is high when the number of individuals within a species is constant among communities. The tropical rain forests contain almost half of the world species with 5–10 million insect species, 40% of world’s flowering plants, 30% of the world’s total bird species; the Great

Barrier Reef of Australia houses 400 coral species, 1500 fish species, 4000 species of mollusks and 6 turtle species. It covers 0.1% of the ocean but has 8% of the world's fish species highlighting species richness [23]. More diverse and rich the ecosystem, it can produce more for use, helps in distributing the resources maintaining equilibrium and can withstand environmental stresses leading to stability and sustainability.

Varieties of ecosystems contribute to ecosystem diversity. It takes into account the number and nature of the ecosystems. The different ecosystems of the Earth include oceans, deserts, lakes, forests and plains, and within each type, there are different environment specificities like hot/cold deserts, Mediterranean/ tropical forests and so on. Each ecosystem has its own specifics, functions, species and peculiarities. When biodiversity is assessed, the parameters taken are all types of living organisms and their interaction and contribution to the ecosystem.

The Amazon Rain forest, one of the most biodiverse regions on Earth, has complex ecosystem, huge mix of species and the genetic variety within the species. It has been estimated that the Amazon Rain forest produces 20% of the total oxygen in the atmosphere of the Earth through photosynthesis [23]. In this forest, there are huge vines which start from the trunk of the trees to the canopy, intertwining with the treetops and their thick wooden stems supporting the trees and branches; the trees provide the fruit and seeds which are carried by the herbivorous animals like Tapir and Agouti, to different parts of the forest enhancing the growth of new plants and providing food for millions of insects [24]. The rain forest is a huge system built on smaller systems packed with interconnected species; every link provides stability to the next system strengthening biodiversity weave. This weave is further reinforced by the genetic diversity within individual species, which helps them to cope with changes. However, there are vulnerable species that lack genetic diversity due to isolation or low population, which are unable to withstand fluctuations due to climate change, habitat fragmentation or disease. In some ecosystems, removing one keystone species will cause the links to fall apart and unravel the entire ecosystem. For example, the coral reefs nurture many organisms by providing key ingredients, microhabitat, nutrient, shelter, breeding ground for thousands of fish, mollusks and cry stations; corals are interdependent with fungi and bacteria enabling a sturdy weave that supports various organisms. Thus, the coral, a keystone organism, if weakened or killed by destructive fishing, ocean acidification or pollution, can in turn affect its dependents and the entire ecosystem. Thus, the ecosystem, genetic and species diversity together form the complex weave of biodiversity vital for the survival of organisms on Earth. Humans are also woven in this weave as they are dependent on nature for resources. Extraction and abundant use of resources without concern for regeneration can disturb the relationships within the ecosystem and facilitate biodiversity loss. Biodiversity helps in ensuring Earth's own protection net to safeguard the survival of all organisms including humans.

In 1972, the UN Conference on the Human Environment held in Stockholm, Sweden, realized the need to regulate the use of natural resources in order to preserve ecosystems and its components. Some of the salient features of the Stockholm Declaration [25] are well represented in Principles 2, 3 and 5. Principle 2 states that air, water, land and the ecological network (fauna and flora) and any other as applicable, the natural resources of the Earth, are to be protected for current and future generations by appropriate careful planning and management. Principle 3 indicates that the capacity of the Earth to produce essential renewable resources (flow resources like water, air, natural energy forms and biomass) should be maintained/restored/improved for optimum use. Principle 5 refers to non-renewable resources of the Earth (coal, petroleum, natural gas, etc.) must be used judiciously to prevent complete exhaustion and to be shared by all mankind. The Stockholm Declaration has addressed many issues like resource depletion, sharing of resources within and across countries, intergenerational equity and a balance between sustainable use to maximize social benefits and minimize environmental impacts.

2.2 Natural Resource Management

We have seen the story behind natural resources and how they work, let us see how we can work toward sustainable resource management. In order to work toward sustainability, we have to understand the term ‘natural resource regeneration’. Any natural resource needs time to regenerate/revive/renew for further use, e.g., cutting branches of trees and estimating the time taken for it to come back to its form before cutting. Hence, it is essential to understand that all renewable resources require time to regenerate. If the renewable resources are not given time to regenerate and is again and again used, it leads to ‘natural resource exploitation’. Hence, there needs to be a balance between the demands of exploitation and regenerative capacities. It is hard to set limits to this issue because of the fact that the Earth has limited resources, its regenerative capabilities and the absolute diversity of natural resources that make scientific assessment difficult.

Basically, natural resource management has two main concepts, namely maximum sustainable yield (MSY) and optimum utilization (OU) [26]. All natural resources have an optimum utilization level or acceptable levels of use. This level is usually set by management authorities or national/international regulatory authority based on scientific knowledge with a purpose of regulating exploitation. The MSY is a regulatory principle that introduces real-life data into the management process. Let’s take the example of fisheries. When death of fish occurs due to human harvesting, the reproduction rates will rise. This is the peak level of production after which the overall population will decrease culminating the positive effect of increased rate of production. When the surplus production is harvested sustainably according to the MSY that is specific to each population, there will be good regeneration of resources that will stay for a long, long time. If the population decreases due to problems like disease or habitat loss, the harvesting should be done according to the current MSY. Hence, careful monitoring of population growth and overall health of the population are required. Measures like reducing the harvest of females or immature fish can ensure the population to be maintained to the required sustainable levels.

Use of natural resources may be consumptive or non-consumptive. In the first case, the resource is consumed effectively that it cannot be put to any other use. Here, management would be balancing exploitation in relation to regeneration capacity of resources. In the second case, humans do not consume the resource, but may interact with them. Management will be in the form of regulation of human interaction and control the negative impacts of such interactions on the resource. Here, management trend will be protection versus exploitation. Whales were used as a raw material and fuel in the West till the mid of the twentieth century; today, they are a recreational resource in the West and as food in other parts of the world. The uses of resources may change and require change in management and outlook. Resources that are localized like forests and collective resources that do not have specified borders namely air & sea, need extra special managerial solutions; selfish motives of excessive usage of these resources can lead to environmental degradation, pollution, and climate change which impact on a global scale. Here, limiting the exploitation of resources to make them available for future is not possible as individuals have the tendency of using large quantities of collective resources before the others get a hand to it. A blend of private and communal management is required which may give rise to problems in resource management.

3 Sustainable Agricultural Practices for Reduced Land Eco-Toxicity

Agricultural practices are considered to be sustainable when the farming practices prevent negative effects to soil, water, biodiversity, other allied resources and the impact on living organisms. This may include regenerative farming, organic farming, permaculture, agroforestry, biotechnology in agricultural practices, mixed farming, multiple cropping and crop rotation. Let's discuss regenerative farming, biotechnology in agriculture and organic farming.

3.1 Regenerative Farming

Regenerative farming is a combination of farming and grazing practices that reconstruct and build the organic matter of the soil, thereby boosting its biota diversity. This enhances the capacity of the soil to absorb, store and sequester atmospheric carbon and increase its water holding capacity. Further, there is a two-way benefit, namely the reduction of CO2 content in the atmosphere which is the cause of global warming and the improvement of soil structure that has been damaged by human civilization. The farming practices can be measured for carbon enhancement of the soil, and the raw material produced in this land is termed as 'Climate Beneficial' [27]. Carbon Farm Funds help in the implementation of farm practices that produce climate beneficial materials, e.g., North Carolina Fibershed. Farm and ranch scale contributions fall between 1 and 3% of the annual point of sale purchase while mid- and large-scale donations include price premiums of 60 cents per pound. Many farmers adopting regenerative farming practices have been given the title of 'carbon farmers'—Lani & Estill of Bare Ranch, California [28]. Reports indicate that climate beneficial production has a carbon footprint differential of 150 pounds of CO_2 per garment when compared with the conventional methods of production [27, 29].

Some of the regenerative practices applicable to fiber farms are compost application on pasture, silvopasture, rotational grazing, conservation tillage, pasture cropping, planting windbreaks and buffers and creek restoration. A half inch layer of compost is applied to the pasture, which slowly releases the fertilizer causing an annual carbon sequestration rate of one ton per hectare for 30 years without reapplication [30]. Silvopasture is a manmade combination of pasture and trees for sequestering large amounts of carbon in the soil; managed rotational grazing allows animals to graze in planned pasture divisions for longer rest periods. Value creation in the minds of the consumer is enhanced by the term 'climate cooling wool' produced by Fibershed for the manufacture of climate beneficial products. Taking the cue, the North Face has introduced its Cali Wool Collection—beanie, scarves and jackets using 'Climate-Beneficial TM Wool' from Fibershed. Regeneration International, a nonprofit organization in the US, networks with 4 million members in more than 100 countries, provides hands-on and online training in sustainable farming and runs a data bank of American and European sustainable fashion brands [29] for eco-conscious customers.

3.1.1 Factors Affecting Regenerative Agricultural Practices:

Water

Fresh water is a scarce resource and requires careful usage. Soil becomes salinized and infertile due to continuous irrigation techniques. Desalination is a technique used for producing fresh water for agriculture. It has been reported that in 2015, 3–5kWhm^{-3} energy was used to produce 100million m3 of fresh water serving as the feasible alternative to irrigation [31]. In the desert and dry areas, water deposited during the night and early morning evaporates during the day. This can be preserved by covering the surface with a layer of fiber waste which cools more quickly, and combined with the porous nature of sand, the absorption of water is higher; the surface of the fiber waste tends to provide space for water to condense. It has been reported that 13% came from the land-surface source and 19% from dew in the semi-arid areas, while conditions of fog can condense more water. A manmade layer of algae in the Qubqi Desert fetched two times more rainwater when compared to the conventional setup [32–35].

Soil Organic Matter

Sequestration of carbon in the soil is an important factor for better farmlands. The soil organic matter (SOM) includes the organic components, namely undecayed plant and animal tissues and their partial decomposition products along with the soil biomass [36]. A study in the arid grasslands reported that the SOM above the ground (155.3), below the ground (95.3) and total was $256.3gm^{-2}$; the mean soil organic carbon density was 1.38 Kgm^{-2} in the top 30 cm of the soil. During cultivation, organic waste is added to increase SOM resulting in increased carbon from the organic waste and carbon sequestration from the vegetation. The estimated sequestration of carbon would last for 155 years. The addition of cover crops would have a potential global soil organic carbon sequestration, which could compensate 8% of the direct annual GHGs from agriculture. This sustainable system is beneficial for grasslands and also decreases waste masses. The waste mass serves to increase the moisture content helping the microorganisms to thrive well and create an environment for the cultivation of plants and trees in the semi-arid areas [37–41].

Cultivation Methods

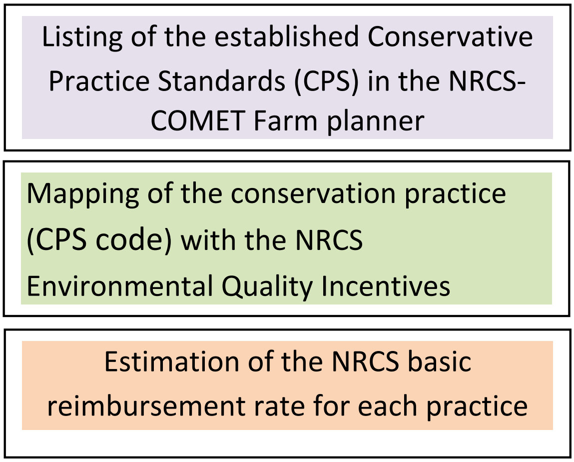
Cultivation methods play a very important role in the successful harvest of any crop. Two methods have been discussed as examples for sustainability. In the first method called Zia, planting is carried out in huge pits (dia 50 cm and 45 cm depth), which are dug during the dry season to act as a carrier for water harvesting and organic matter. The organic matter is filled in the pit and further up to give a cone-like appearance on the tree trunk/ base of the bush planted in the rainy season. This process is self-reinforcing and helps in SOC process year by year. The second method is to spread a 0.2-m-thick layer on the surface of the area, which promotes water absorption and increases SOC [39, 42–44].

No till or low till farming is a sustainable agricultural technique that leaves the top soil undisturbed for the growth of mycorrhizal fungi which helps the symbiosis of crop roots and earthworms to provide better outcomes. The farmer tills about one feet deep and loses the crop residue by 90% and also leads to erosion by wind and water.

Carbon Content of Textile Fibers

Textile waste materials are used as a resource for energy. The amount of carbon released into the atmosphere while burning textile fibers is dependent on the cellulose content of the material; for example, cotton consists of 90% cellulose [44]. One ton of cotton when burned releases (1000kg $\times$ 90% $\times$ 0.444) 400 kg t^{-1} carbon and 1.47 t CO_2. Synthetic polymers and wool tend to produce more amount of CO_2. It has been estimated that the textile incineration (municipal solid and textile waste) is around 78650t leading to CO_2 gas of 115600t per annum [45, 46]. The cotton waste

Fig. 2 Funding system for conservative practice standards [50]



can be converted into fertilizer to improve the SOM. The density of compressed textile waste is estimated to be 265kgm^{-3}, 17,700 kg cotton can supplement the biomass on 11.4 ha at the cost of $270 to $600 per hectare, and the breakeven cost as a cheap alternative will be achieved by 20 years. When the fertility of the arid soil is increased by such agricultural practices, the farmlands fetch a better price.

Uses of Textile Waste

The Waste Framework Directive (WFD) recommends the following system to be followed with regard to waste segregation, namely prevention, reuse, recycling, other recovery and disposal. In Sweden, the textiles left in the municipal solid waste were reported to be 77100 tons out of a total consumption of 121000 tons. A majority of this waste was burned in power plants by incineration. This could be used for improving the SOM. Technological advances have helped in segregating waste textiles according to the inherent raw materials. Near-infrared reflectance spectroscopy (NIR) has been used to identify components of textile waste. In 2017, Fibersort is running a 5000 t capacity facility for waste segregation. NIR also helps in estimating the carbon content of the waste collected [45–49].

Implementation of Conservation Practices—Costs and Funding

Regenerative farming practices for wool production in North Carolina are an interesting aspect for analysis. When a conservation practice is introduced, the ranchers generally want to know about the benefits of adopting the practice and what will be additional value that will be incurred. A basic rate for the conservation practice was fixed as mentioned in Fig. 2. A farmer who has a 10 acre holding, non-organic and 80 sheep may be interested in two conservation practices like ‘cover crops – CPS 340’ and ‘mulching-CPS 484’ for which the basic reimbursement rate is $61.91 and $188.28 per acre, respectively. The farmer will use 4 acres ($274.64) for cover crops and 2 acres (376.54) for mulching leading to a total of $624.20. The non-reimbursement funds are usually around 50–85% ($312.10–530.57), which may be earned by the higher price of wool or from grant funds. This encourages the farmer to start the conversion and slowly convert the non-organic farm to a sustainable one.

A regenerated fiber fund was set up by Fibershed to fund on-ranch conservation practices in three different models. The first model is *Regenerative Premium on Raw wool,* which pays an additional cost over the market value ($0.60/pound) to the rancher who produces regenerative wool. The rancher benefits from the immediate returns, but it add costs to the supply chain increasing the price at different stages (up to $2.40/pound). This model is considered as most effective. The second model is *Regenerative Wool Premium on Textile Products* adding value to textile programs. Here, 3% is added to the textile sales price which is paid to Healthy Soils Fund initiated by Fibershed to distribute to the ranch partners. The funds help Fibershed to build regenerative fiber arrangements and also create awareness by consumer education through a point of sale model. This system was taken up by Houston Textiles, which eventually became a tax deductible donation for the company. This model was less effective in raising money for the ranchers but helped in creating awareness among the consumers and general public. This system facilitated Fibershed by creating funds for future regenerative wool programs. The third model is a donation to the Regenerative Fiber Fund either as an $8 tree donation per linear foot of tree planted area or a $50 ‘compost donation’ for one cubic yard of compost application [50]. This model includes a wide range of supporters who are not into the fiber processing business but are interested in promoting regenerative products. This model is considered least effective but helps in raising capital to fund future practices.

3.2 Biotechnology in Agriculture

Biotechnology is a valuable tool for the implementation of sustainable agriculture. The production systems have been drastically changed with the advent of biotechnological advancements. The biotechnological shift helps to nurture the environment, enhance the quality of life and also instill economic progress. In 2005, about 21 countries had grown transgenic crops like maize, canola, cotton and soya bean of which 14 countries had covered more than 50,000 hectares with these varieties. In 2005–2006, about 28% of the total global agricultural area was growing biotech cotton varieties (insect resistant IR and herbicide resistant HR), which represented 37% of the total cotton bale production and 38% of the global bales exported [51, 52]. The main aim of developing IR and HR cotton was to produce plants what could control lepidopteron insects and to protect the plant from a variety of herbicides using gene technology. Cotton varieties are available with multiple output traits like agronomic performance, gossypol reduction, fiber quality and abiotic stress tolerance.

Agronomic sustainability is based on rotation of crops, integrated pest management IPM, use of multiple technologies and cultural practices leading to the prevention of over farming and soil erosion which are the perennial threats to the cotton-cultivated areas across the globe.

The major goals for sustainable cotton production are environment positive, economic and viable and enhancement of the quality of life, which can be achieved by catering to the growing demand of the fiber, maintaining the natural resource base and adopting sustainable farming operations. Cotton faces the challenge of being replaced by manmade synthetic fibers if it does not maintain the qualities of production and operations coupled with biotechnological developments. Reports state that the use of IR cotton varieties shows that there was a 14% (−1.2 million kg) reduction in the use of insecticides in six US states showing improvements in surface and ground water quality which would otherwise be contaminated by runoff and leaching of residual chemicals [53, 54]. This feature is shown in Table 2 and Fig. 3. The use of HR cotton has increased the yields showing an increase in pounds and a reduction in the herbicide application. While working on the economics, five studies taken in seven states have shown that on an average the increase in returns was $8.42 /hectare with an increase in yield by 9%. The introduction of IR cotton proved to be beneficial as the profit earned was around $99 million in the year 1999 when compared to the conventional cotton production and cost in the previous year [55, 56]. The benefit of using IR cotton with stacked genes could be understood by the report which states that the $28.70 was the economic advantage or $4.23/hectare [57, 58]. A similar

Table 2 Cotton herbicide application [1994–1999] [59]

Year	Lbs/acre	Applications (per acre)
1994	2.02	2.96
1995	1.89	2.91
1996	1.57	2.53
1997	1.7	2.84
1998	1.61	2.76
1999	1.63	2.82

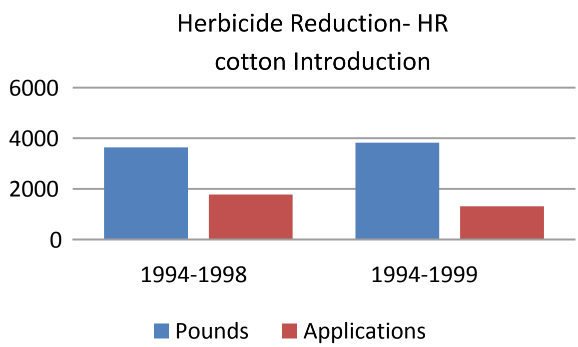


Fig. 3 Carpenter and Gianesse [53]

sequence was seen in 2005 when India expanded the plantation of IR cotton hybrids by 160% with the cultivable area of 1.3 million hectares by one million farmers. ICAR conducted many studies, and the cost–benefit analysis of IR cotton showed an increase of 67% in gross income on an average with yield increases from 62 to 92% [59].

The quality of life is a social aspect in the drive to sustainability. BT cotton has brought safety to human health in terms of reduced pesticide use and exposure. In China, the incidence of symptoms by pesticide poisoning significantly reduced by around 80% demonstrating the health advantage of using IR cotton [60, 61]. Further gossypol content in cotton seed makes it unsafe for animal and human consumption [62]. It has been estimated that the annual yield of 44 million metric tons of cotton seed with 9.4 million MT of protein could address the total protein requirement of half a million people @ 50 gm/day. Biotechnology is helping to bring about this conversion for human health and nutrition and to cater to the food requirement of the world population which has been predicted to increase by 50% in the next 50 years. Another important feature is the ease with which IR/HR cotton can adapt to technology and also holds reduction in labor inputs, e.g., it takes 3 h to stack a bale when compared to 25 h in conventional cotton [63].

3.3 Organic Farming

A twentieth-century development is organic farming which relies on the concept of nature-based agriculture. This system uses growth boosters of organic origin and also uses sustainable methods of agriculture. Some of the organic fertilizers used are compost manure (manure from animal feces), green manure (manure from plant origin and farming left outs) and bone meal (ground animal bones and slaughter house remains), and the techniques adopted are crop rotation (growing different crops in the same area), companion planting (planting different crops in proximity), biological pest control (controlling pests with natural predators), use of natural insect killers and elemental synthetic substances (copper sulfate, sulfur, lvermectin). Substances like genetically modified organisms (organisms with modified genes), nano-materials (substances between 1 and − 100 nm), hormones, human sewage sludge (semi-solid remains after any process), plant growth regulators (signal molecules in low concentration which promote growth) and use of antibiotics in animal husbandry (synthetic medicines for livestock) are prohibited in organic farming [64–66]. Organic agriculture is internationally monitored with a set of standards by International Federation of Organic Agriculture Movements (IFOAM) founded in 1972 [67].

Organic farming works for soil fertilization and health; enhancement of biological activity by the use of cover crops, green and animal manure and crop rotations; weed management and insect and disease control by the use of biological means and crop rotations; better augmentation of biodiversity of system with environment; improved livestock operations and health care of animals using rotational grazing and mixed forage pastures; reduction of waste and 'of the farm inputs' through elimination of chemical fertilizers, pesticides, synthetic medicines and antibiotics. The whole perspective in organic farming is an emphasis on renewable resources, conservation of soil and water, and agricultural practices that enhance environmental equilibrium. There is a growing awareness among all sectors of the population about the benefits of organic farming and products, and it has been reported that in 2016 about 57,800,000 hectares have been farmed organically, which represents 1.2% of the total land around the globe [66, 67].

Organic cotton initiatives were started in Asia, Africa and S. America due to market demand and retailers option for organic garments. In 2006, the production of certified organic cotton was 31,000 tons and the turnover for organic cotton garments reached US $583 million [68, 69]. Trials were conducted to check the productivity difference between organic cotton and conventional cotton. The report given by the Central Institute of Cotton Research, Nagpur, and a pilot study in Andhra Pradesh, India, showed higher yields 11-21% and 13%, respectively, in the case of organic cotton [70–72]. In India, the gross margins were higher for organic cotton when compared to conventional cotton by 52% in 2003 and 63% in 2004 reducing the financial risk for the farmer. Organic cotton also had a premium price and the intermittent crop also contributed to the profit. However, there are obstacles in the initial stages of organic cotton cultivation. The conversion from conventional farming to organic farming takes 3 years when the yields may decline from 10 to 50% [73, 74]. This is usually attributed to the time necessary for the soil fertility and ecological balance to respond to organic nutrients and pest management; the farmer also needs training in organic farming and management and requires hard work, immense patience to bear with the pressure of weed and insect management during the initial stages.

4 Water and Energy Management

4.1 Water as a Natural Resource

Sources of water that are useful to humans are considered as 'water resources'. We see so much of water around us that it gives an impression that it will last very long, say a million years. The Earth is referred to the 'Blue Planet' as three fourth of the surface is made up of water [75]. Data indicates that fresh water contributes to only 2.5% of the total water on Earth and two-thirds of this water is found in glaciers and at the polar regions. Fresh water may be from two sources such as surface water (ponds, rivers, lakes and streams) or ground water (water that seeps into the ground and trapped between soil and rocks). It has been estimated that 70% of the water in the world is used for agricultural irrigation [76]. The impact of climate change will be heavily felt on the water resources as there is a close connectivity between climate and the hydrogen cycle. Use of water by mankind has depleted the aquifers and many pollutants are a great menace to water supplies.

Since water is a renewable resource, it is comforting to think that we can get back water if used with great care. Limitless exploitation of this resource can lead to depletion. The United Nations Development Plan states that when annual water supplies reach below 1700m^3 per person, it is termed as 'water stress', and when the annual supplies drop below 1000m^3 per person, we can say that the area is experiencing 'water scarcity'. The prediction is that there will be severe water scarcity in Africa and West Asia by 2025 due to high water demands [77]. Another school of thought predicts that the planet Earth could become barren and dry like the planet Mars within one billion years as the oceans are slowly going into the interior of the planet. The Tokyo Institute of Technology has estimated that annually 1.12 billion tons of water moves from the oceans into a layer of rock found in the interior of the Earth called the Mantle [78]. This movement has caused the sea levels to fall down by 600 m in the last 750 million years. Scientists also believe that water can return back to the surface through volcanos and mid-ocean ridges, and annual return of 0.23 billion tons, which is far below the required level. Water being precious should be used with utmost care and managed well to prevent wastage.

4.2 Water Management

The raw material for fashion and apparel industries is textiles, and cotton is primarily used for a majority of apparels. World Wildlife Fund (WWF) has indicated that 73% of the cotton supply of the world is nurtured in plantations using natural irrigation. This will in turn reduce the supply of water over a period of time. The Aral Sea in Central Asia [79, 80] is the best example where the waters of the feeding rivers Amu Darya and Syr Darya was diverted to grow cotton and agriculture. The Aral Sea, the fourth largest inland water body, dried up creating an ecological catastrophe. The sea shrunk by 1994 to form two entities and the water and vegetation became salty; the animals who ate the grass fell ill and many animals would bang their heads on the ground and die. After some time, the Kokaral Dam was built between the Large and Small Aral seas that caused water to flow back to the Small Aral Sea. Lesser salt, fish came back and people who left the place started coming back. However, the impact has been great and the people are waiting for some miracle to occur—to see water in the Aral Sea to make it once again the fourth largest inland water body of Central Asia.

Steps to improve carbon footprint and reduce water wastage:

- Agricultural innovations: use of recycled water for cotton plantations, save water through new technologies.
- Raw material: use of environment friendly raw material, e.g., biocotton; unconventional sturdy fibers, e.g., hemp, linen, nettle and flax that require less water fertilizers and pesticides; recycled fibers can cut the water footprint when compared to virgin fibers. Osomtex, a US-based yarn brand, has zero water in the process as it follows mechanical recycling. Similarly, EcoAlf, Spain, has marched forward by recycling plastics from the ocean into clothing [81, 82]; upcycled fibers to produce less water intensive fabrics. In 2016, Levi Strauss & Co. teamed up with Evrnu for producing Levi's 511 prototype from five discarded cotton t-shirts. The cotton waste is pulped and then extruded into a new fiber which is finer in denier than silk and stronger than cotton [83] and 98% less water usage compared to

virgin cotton products. Blue Ben, German label has opted for a biodegradable viscose developed by a Portuguese firm Tintex, thereby saving 94% water that is consumed by conventional cotton [84].

- Use of new technologies in textile manufacture. Wet air oxidation is a viable method that converts pollutants into water and CO2 at high temperatures of 300 oC and high pressures of over 10 MPa for efficient conversion within the stipulated time without additional sludge or concentrated waste as by-products [85]. Can be used for treatment of all wet processing wastewater of the textile industry. Similarly, SpinDye, Sweden, has chosen to dye polyester before spinning leading to a reduction of C02 emissions by 30% and water consumption by 75% [86].
- Sourcing of sustainably grown cotton based on international standards, e.g., fair trade certified or Better Cotton Initiative and so on.
- Partnering with manufacturers who recycle and reuse process water, keep processes on no water or least water menu [87]
- Technological improvements and research should be directed to find ways of recycling water and reuse in day-to-day manufacturing. Favorable and commercially sustainable practices and their success should be made aware to the textile and apparel fraternity for similar initiatives and attempts [88].
- Eliminating hazardous chemicals in clothing manufacture by incorporating Detox best practices in chemical, water or textile-related regulation (national or global legislation) with rewards for sustainable followers.
- Chemical and sourcing transparency and safe alternatives: adoption of hazard elimination roadmap, research for safe alternatives and closed-loop production processes.
- Increasing the lifespan of individual clothing through reselling and rental. Efforts have been taken by Selfridges, London, to become a zero emission business enterprise by 2050. The retailer has vowed that by 2025, it will have products that are made from materials that adhere to sustainability standards and will be assessed continuously as per the requirements specified by certification bodies and green groups [89]. Selfridges has partnered with Vestiaire Collective, second-hand market place for luxury fashion in 2019 and in 2020 launched 'Reselfridges' where customers can buy and sell luxury second-hand articles. Further, in May 2021, Selfridges has associated with Hurr, a rental platform, to start 'Selfridges Rental' which enables customers to rent in the season stock. Similar reseller market place has come into existence like Levi's Secondhand, COS Resell, etc. A report states that if the life cycle of cotton garments is extended by nine months, the water footprint of clothing can be reduced by 5–10% [90].
- All manufacturers, retailers and suppliers need to estimate their products and services in terms of sustainability impacts—environmental, social and economy. H&M, in June 2021 has followed the HIGG Index ranking for their products similar to the traffic light system which will provide an insight to customers regarding the water use and pollution impacts of their products. A scoring system is used; the baseline score indicates that the materials that constitute in making the product are not biodegradable, while products with scores 1,2,3 show that the biodegradable materials have been used in the product, with 3 showing the highest

degree of sustainability. The report states that six products in the H&M website have score 3.

In the COP24 climate conference in Poland, 43 companies signed the UN Fashion Climate Charter with the aim of achieving ‘net zero greenhouse gas emissions’ by 2050. Water scarcity is a looming threat and it has been predicted that by 2025 two-thirds of the world’s population will have to live in water-stressed regions [20]. Greenpeace’s focus on water pollution and its reduction followed by UN’s declaration naming the decade as ‘Water Action Decade’ have increased awareness and responsible action.

The UN Global Compact has announced the CEO Water Mandate, with an aim to mobilize business leaders on the issues of water, sanitation and SDGs. As on date, 203 companies have endorsed to work continuously toward six core elements of water stewardship. This will enable all members to understand to manage one’s own water-related threats. The six core areas of water stewardship are: (1) direct operations—include those who directly or indirectly use water for the production of goods and services; (2) supply chain and watershed management—include water-related activities along the supply chain; (3) collective action—encourages collaboration between stake holders across sectors and societies; (4) public policy—provides inputs and develop policies at local, national and international levels; (5) community engagement—initiates community and local-level awareness and education on water; (6) transparency—reporting, accountability and sharing of water strategies [91]. Each core area has a description of the goal, target and pledge that the members have to endorse for continuous effort and action.

The Water Action Hub is an online global knowledge sharing platform with 1694 projects, 1065 organizations at 5595 locations in different parts of the world [92]. The hub helps in promoting awareness of organizations and their sustainability projects, facilitation of new projects, partners and collective action to address water-related risks and sustainable management of water and join the Water Resilience Coalition to reduce water stress. Users/members can access the projects from any part of the world and understand the problems, process and technical solutions to face the challenges of water stewardship. Thus, water as a natural resource requires serious deliberation before use, and its management is very critical for regeneration as a resource for future use. Many organizations and individuals are facing the impact of overuse of water and are looking forward to stringent measures to protect and save this precious resource for future applications.

4.3 Natural Resource: Energy

The next important natural resource is energy which is the most needed item in today’s world. Matter that stores energy is named as fuel. Energy is the capacity to do work and can be in many forms, namely thermal and radiant obtained directly from the sun, electrical and mechanical acquired indirectly from the sun, chemical and atomic energy which are independent and not from the sun. Atomic or nuclear energy is the heat generated by the splitting of atoms (fission) or by the fusion of two atoms. The sun's energy is created by the fusion of atoms. The by-product of nuclear fission is radioactive waste which will last for 500,000 years. Nuclear fission has been existing from World War II [93, 94].

Natural resources from the energy perspective are termed as primary fuel resources—coal, oil, natural gas and uranium. Their occurrence on the Earth is in the form of deposits that have to be discovered and extracted. These fossil fuels are non-renewable and predicted to decline. It has been estimated that 90% of world's energy needs are fulfilled by fossil fuels; they provide 66% of the world's electrical power and 95% of the world's energy requirement leading to an alarming statistics of doubling consumption of fossil fuels every twenty years [95, 96]. The primary energy flow resources are the wind, hydro and the solar and are freely available as there is no reservoir unlike the primary fuel resources [97]. Solar energy can be used in many forms for different applications, namely thermal heat, ventilation (stack effect), shading (blocking the direct sun), radiant cooling (absence of sun in outer space at night), day light (natural light), photo chemical (reactions of sun and materials) and humidification (evaporation using energy from the sun). A tiny fraction of one percent of solar energy, which is absorbed by the Earth, is changed into plant tissue that has produced all the fossil fuels. Harvesting fossil fuels and burning them for energy can be hazardous to the environment. It will take thousands of years for the Earth to reproduce the consumed fossil fuels as they are non-renewable resources [93].

Air mass is another natural resource for the production of energy. The radiant heat from the sun is unequal on the surface of the Earth; this produces differences in the heat contents and density of the air mass causing movement that is amended by various factors like rotation of the Earth, inclination, distribution of land and oceans followed by geographic abnormalities. This movement of the air mass is termed as wind. Wind energy can be used in many ways like cooling, promoting combustion, as windmills for pumping water and electricity. Likewise, the movement of water in its natural cycle can create energy, namely hydro-electric dams, turbines, ocean thermal gradients, tidal power, thermal inertia and thermal storage by water.

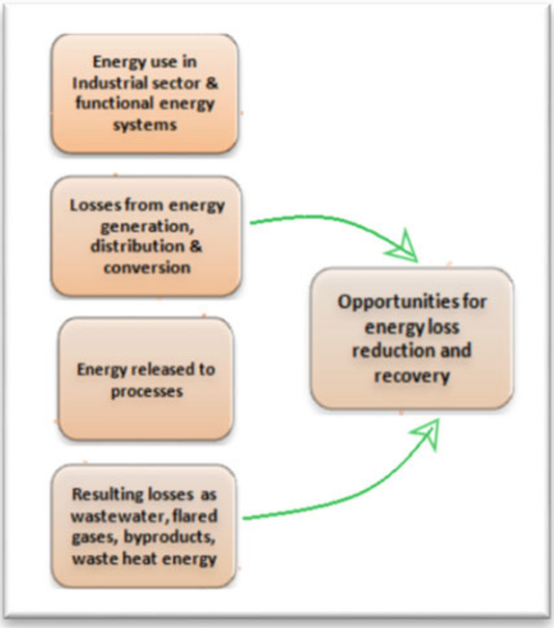
Economic development and energy consumption go hand in hand. Generally, economy grows to meet global competitiveness and is based on availability of low cost, environmentally safe energy sources and the ability to meet energy demands. The need for renewable energy is progressing at a rapid pace, and the focus is on enhancing the distribution and transmission infrastructure and improvement of conventional, hydro and atomic energy followed by energy storage. Whatever may be the energy demand, the production rate of a resource must be studied to understand the replenishment time. This will keep the resource alive and supply the resource consistently. Hubbert's curve [98] is a model that estimates the production rate of a resource over a period of time. In this estimation, the Hubbert's peak refers to a point where the production rate will be the highest with the demand for the resource rising after which there will be a drop in production compared to the demand. This was originally devised for the US oil production. Hence, more consideration should be evident to control the use of resources in an optimal way to enable the replenishment of the natural resource.

4.4 Energy Management

Industry and the nation will obtain substantial benefits if the efficiency of energy is increased. To understand and assess opportunities for increasing energy efficiency, one must identify how the industry is using energy, amount used for various systems, loss percentage and quantity that goes into processes. Next, the energy that can be recovered through energy efficiency, technology and other means is to be assessed. Research is being conducted by the US Department of Energy's Industrial Technologies Program (DOE/ITP) to fasten environmentally viable and energy efficient technology for industry through a multiphase study to identify the usage of energy sources and systems, target opportunities for reducing the use of energy and increase the conversion of energy resources into useful production output. This can be best understood in Fig. 4.

To start a study on energy recovery, primary energy and fuels and electricity have to be taken into account. Primary energy represents all the processing energy related to the industrial plant boundary, both internal and external. Primary energy use comprises of power and fuels and the losses that occur at the site from where the

Fig. 4 Energy use, loss and opportunities in industrial production



energy is purchased. However, it does not include the energy used as raw material often termed as ‘feedstock energy’. The next part of the study is the comparison which identifies industries as either electricity intensive or fuel intensive. The potential for onsite cogeneration technology can be understood. The onsite energy losses usually occur in process heating and cooling and hence one must take into account steam systems, fired systems and the cooling systems. The potential downstream losses are usually not given due care and can be as much or more than those prior to the process. Opportunity analysis will help to reduce and recover the energy losses to a great extent to bring about cost reduction and savings.

Coming to the textile industry/mill, conversion of electrical energy into mechanical energy is important. Usually, the conversion efficiency is 85% and this should be stepped up to provide monetary savings. The type of motors and their output play a significant role in energy savings. Energy conservation can be achieved by minor change of equipment, high capacity utilization and technology upgradation. In India, two forms of energy are used, namely electricity (spinning) and fuels (wet processing), and the share of energy expenditure in manufacturing cost is increasing and has moved from 12% in 2003 to 18–20% in 2017 [99]. Let’s take the case of the US textile industry steam and motor-driven systems account to 28% of the total energy use and the estimation of onsite energy losses is around 13% in motor-driven systems, 8% in distribution and 7% in boilers [100].

While considering energy efficiency, the utilization of light source, use of multiple motors with control board and electric heating vs other methods should be examined in the case of motor-driven systems; for efficient fuel use, selection of fuel and boiler to prevent pollution is efficient; with regard to steam losses, selection of transportation pipes, installation of steam accumulators and heat exchanger are important. Use of non-conventional energy sources is a must as maintenance cost will be low, pollution will be almost nil and there will be no wastage. An energy audit will help to identify problems and promote energy conservation.

Use of energy is always linked with greenhouse gas emissions. Managers and engineers in the textile and apparel industries need to track their energy usage and in turn the GHG emissions. To aid these personnel, a suite of tools is available, namely [101]

- Textile and Apparel-specific Tools: Energy Efficiency Assessment & Greenhouse Gas Emission Reduction (EAGER) Tool; SET Tool; Energy Distribution Support Tool (EDST); Energy Management & Benchmark Tool(EMBT); Self-Assessment Tool (SAT).
- US DOE Energy Assessment Tools: MEASUR Tool; 50,001 Ready Navigator Tool; Energy Performance Indicator LITE (EnPI LITE) Tool; 50,001 Ready Navigator; Energy Footprint Tool; the Plant Energy Profiler Excel (PEPEx) Tool; Steam System Modeler Tool; the Process Healing Assessment and Survey Tool (PHAST); MotorMaster + Tool; AIRMaster + Tool; Pump System Assessment Tool (PSAT); Fan System Assessment Tool (FSAT).
- USA EPA Tool: Energy Tracking Tool.

Thus, the water footprint and energy footprint help in bringing to the notice of the industry many salient ways and technologies to conserve the natural resources. These resources are scarce and subject to high price volatility. However, the most appropriate and effective technologies are not implemented due to limited knowledge and awareness about how to incorporate efficiency measures into the day-to-day functioning of the industry. Expertise related to water and energy efficiency technologies and practices, implementation techniques and their results have to be disseminated to all concerned to motivate and encourage them to follow and attain benefits.

5 Certification of Sustainable Textile Fibers

Many certification and standards have been set up for sustainable textile fibers of which a few will be discussed.

5.1 Textile Exchange

Textile Exchange is a nonprofit organization initiated in 2002 with headquarters in Texas and has branches in 11 countries and 25 member countries. Some of the standards of sustainable concern are Content Claim Standard CCS, Organic Content Standard OCS, Responsible Down Standard and Responsible Wool Standard. The content claim standard verifies the organic integrity of input materials as mentioned by the vendor. The organic content standard verifies the accurate amount of organic substance in the final product. The CCS and OCS go hand in hand with each other. The Responsible Down Standard RDS ensures that the birds have been nurtured well to express innate behaviors, healthy living with no pain, fear or distress. This standard follows the product from the baseline to ensure that the raw material comes from ducks and geese that are reared in a responsible manner. Similarly, the Responsible Wool Standard (RWS) identifies the best practices of the farmers and checks the wool comes from farms and sheep treated in a responsible way. Textile exchange also recognizes the SDGs and incorporates the requirements as per the regulations [102, 103].

5.2 The Organic Trade Association (OTA)

is an association that promotes and protects organic agriculture with a vision to achieve excellence in agriculture and commerce and protect the environment for the well-being of the society as a whole. With its headquarters in the US, it represents 9500 organic business across 50 states. Organic 101 (eco label) is a standard that has given specific federal requirements for growing and processing organic products [104, 105]. The National Organic Standard Board NOSB states the allowed and restricted substance list for verification and understanding. A detailed application needs to be given by the organic business organization after rigorous announced and unannounced audits by inspectors and consumers. The system is transparent and checks from the agricultural aspect in terms of growing, post-harvest, preparation, processing and handling of the product in par with the federal organic standards. Annual reviews and inspection follow after issuing the organic certificate.

The National Organic Program NOP covers the production of agricultural commodities like cotton and wool in the raw material stage but does not include regulations for manufacturing stage. Hence, this cannot be applicable to garment manufacturing and textile processing. Manufacturers look out for certification from GOTS which has standards and regulations for all stages of apparel or product development (spinning, knitting, weaving, dyeing and finishing) with organic fiber. Both these two standards are taken in union to make it 100% organic.

5.3 International Federation of Organic Agriculture Movements (IFOAM)

The federation, founded in 1972 with headquarters at Bonn, Germany, has affiliates in over 120 countries. The primary aim is to work toward sustainability in agriculture right from the field to the consumer, building awareness and helping the transition of farmers to organic agriculture. The administrative structure of the of the federation includes a World Board which appoints affiliates and gives directions to undertake work—regional bodies to formulate alliances on a regional scale and sector platforms for specific priorities.

IFOAM standards include the IFOAM family of standards which are for global use and for countrywide use. The global standards are International Standard for Forest Garden Products (FGP) and Biocyclic Vegan Standard. There are standards which are country specific as given in Table 3

The Family of Standards is officially endorsed by the Organic Movement and Standards with both private standards and government regulations as required. The IFOAM Standard and IFOAM Accreditation have services for certifiers [106, 107].

5.4 Global Organic Textile Standard

This standard (GOTS) was introduced in the year 2006 encouraged by the growth of organic fibers and the demand for a wholesome certification suitable for industry and retailers. The organization is comprised of 4 reputed organizations: Organic Trade Association (OTA), USA; Internationalen Verband der Naturtextilwirtschaft

Table 3 Family of standards—worldwide [106]

Sl. No	Name of the Standard	Country
1	Tunisia Organic Regulation East African Organic Product Standard The SAOSO Standard, South Africa Zimbabwe Standard for Organic Farming, Zimbabwe	Africa
2	Asian Regional Organic Standard Saudi Arabia Organic Standard China Organic Standard India Organic Standard Israel Organic Standard Japan Organic Standard HKDRC Organic Standard, Hong Kong Biocert International Standards, India ACT Basic Standard, Thailand	Asia
3	National Standard for Organic and Bio-Dynamic Produce, Australia New Zealand Organic Export Regulation Australian Certified Organic Standard, Australia NASAA Organic Standard, Australia Pacific Organic Standard	Oceania
4	EU Organic Regulation Switzerland Organic Regulation Turkey Organic Regulation Bio-Suisse Standard, Switzerland Krav Standards, Sweden	Europe
5	Argentina Organic Regulation Costa Rica Organic Regulation Ecuador Organic Regulation Canada Organic Regulation USA Organic Regulation DIA Organic Standards, Argentina IBD Organic Guidelines, Brazil	The Americas

e.V. (IVN), Germany; Soil Association, UK; and Japan Overseas Cooperative Association JOCA, and other international stake holders with rich expertise in organic farming [108, 109]. Universal recognition for this system was due to the ease of getting one certification for organic textiles and products bearing an assurance of reliable quality and consumer acceptance. Any textile product with 70% organic content can be certified by this system and caters to the environment and social side one. Environmental and toxicological criteria govern the ecological side of the system with reference to input material like dyestuffs and auxiliaries and output like residues and waste water. The system monitors with a ecolabel, the growth and harvest of raw materials till the product reaches to consumer. All stages of manufacture in the textile supply chain are examined based on the quality assurance, revision principles and review procedures.

5.5 Organic Farming Certification

In India, this certification is governed by the National Program for Organic Production (NPOP), Ministry of Commerce and Industry. The organization provides standards for organic production, systems, criteria and accreditation. The standards have been formulated in harmony with the international standards and those complying the procedures can use the organic logo for their products. The organic crop production will include the crop production plan, conversion requirements, duration of conversion period, landscape, choice of crop and varieties, diversification in crop production and management plan, nutrition management, pest, weed and insect control, contamination, soil and water conservation and collection of non-cultivated material of plant origin. Based on the inputs, assessment and review, the certification will be provided with a logo.

5.6 The Sustainability Framework of Food and Agriculture Systems (SAFA)

The FAO has developed a universal framework to assess food and agricultural systems SAFA. After 5 years since inception, the organization has provided the SAFA guidelines, indicators and tools and app that are user friendly and easy to participate. Since this framework is adaptable, the Cacique Guaymallen water management program in Argentina used this tool to assess the sustainability of the local hydrological system working in union with FAO regional office for Latin America and the Caribbean [110]. The area was divided into sustainability polygons, and different trials were undertaken. SAFA framework was used to select the most sustainable alternative for decision making and adoption. The sustainability goals fall under the umbrella of FAO.

5.7 Field to Market: The Alliance for Sustainable Agriculture

Field to Market: The Alliance for Sustainable Agriculture is a platform for creating a sustainable agricultural supply chain for continuous increase in productivity, environmental concern and societal well-being. The food, farming and agriculture industry will benefit and create safe and eco-friendly food, fiber and fuel. The main fundamentals of this organization are supply chain transparency, worldwide collaborations and technological tools and resources that works toward continuous improvement. The trend in this organization is to bench mark, catalyzing and enabling sustainability claims.

The assessment framework called Fieldprint Platform (Fig. 5) helps retailers, suppliers and brands to check at every stage and the environmental impacts of the crop

Fig. 5 Goals of Fieldprint Program [111]

production for continuous improvement. Eight sustainability metrics are embedded in this platform as given in Table 4.

These metrics are service-based tools that measure the environmental outcomes of individual farms and have been in use for over a decade. The Metrics Committee reviews the metric once in three years and revisions, and updations are made based on field experience. The Metrics Standard Operating Procedure describes the process involved in use and estimation of data.

5.8 Responsibility-Inducing Sustainability Evaluation (RISE)

This standard is a method of estimating the sustainability (economic, social and environmental) of agricultural production at the farm level. The RISE methodology has been used in more than 3300 farms and in 57 countries across the globe [113]. In the RISE method, a sustainability aspect is evaluated on the basis of goal definition, farmer selection, data collection, interpretation, feedback discussion and conclusion. The data collected after a series of interviews, visits, inspection and reviews is scored, and the calculations are done on the reference data found in the RISE database involving a normalization process and represented as a scale. All scores are represented by a color code with points ranging from 0 to 100 with the rating description as unacceptable to fully sustainable. Color code red is denoted as 'problematic' and falls between the score range '0 and 33'; color code yellow is specified as 'critical' and the score range is '34–66'; color code green is rated as sustainability 'positive' and the score range is '67–100'. The ratings also take into consideration

Table 4 Metrics for sustainable agriculture supply chain [112]

Parameters	Specifications
Biodiversity	Measures the capacity of the farm/land to support a community of plants and animals—Habitat Potential Index HPI, 2018
Energy	Is an efficiency metric that calculates the complete energy consumption from pre-planting to sale and estimates the energy used for unit of crop production; has seven sub-components based on the specificity of the crop—Energy Use Metric, 2009
GHGs	The Green House Gas Emissions Metric, 2009, calculates the total emissions from four main sources: energy use, nitrous oxide emissions from soils, methane emissions and residue burning emissions. The efficiency metric is the total GHGs per unit crop production
Irrigation water use	The Irrigation Water Use Metric, 2009—an efficiency metric that estimates the amount of water required to achieve an increase in crop yield
Land use	The Land Use Metric, 2009, estimates the productivity of the planted area/land used to grow the crop
Soil carbon	The USDA NRCS tool—Soil Conditioning Index (SCI) is used for the Soil Carbon Index, 2012, to estimate the change in soil carbon as it is important in supporting water and nutrient holding capacity, crop productivity, carbon storage and water infiltration
Soil conservation	The Soil Conservation Index, 2010, uses the USDA NRCS Integrated Erosion Tool IET which has two models, namely Water Erosion Prediction Program WEPP and Wind Erosion Prediction Service WEPS. The metric reports the tons of soil lost per acre by wind and water erosion
Water quality	The Water Quality metric estimates the loss of essential substances like nitrogen, phosphorous, sediment and chemicals from the field due to water runoff. It uses USDA NRCS Water Quality Index (WQlag) for its calculation

the local conditions, and the scores are weighted accordingly, e.g., arid and humid climate, water scarcity, etc. In this example, the farm scores 68, and hence, it is being rated as being in the sustainability track.

The sustainability of the agricultural practices was analyzed in four locations of the Gumera watershed of Lake Tana in the Nile LWP project. Problems identified were soil erosion by heavy mechanical cultivation without erosion control measures, water pollution by livestock feces, lack of manure and water management. The farmer was trained and oriented toward better agricultural practices to maintain sustainable agricultural production.

A study was undertaken where 29 farms in Lake Tana Area, Ethiopia, were assessed and RISE indicator values were estimated. The suggestion given was to improve water management to improve crop productivity and feed production. Water conservation and prevention of pollution were the most important criteria along with safety for human and animal health. Similar efforts were carried out throughout the world with specific goals like optimizing scare irrigation water resources for increase in crop productivity, methods for increasing livestock water productivity, improvement of rain-fed cropping by integration of germplasm for sustainable water productivity, coordination of multiple use system by water management systems and tools for water management.

6 Green Productivity and Sustainability Reporting

6.1 Cleaner Production

Cleaner production is another term for green productivity. Resource use and production process in sufficiency and inefficiency result in pollution and waste. When these two hazardous by-products are consciously reduced or eliminated, we will be moving a step forward to green productivity. There are two important concepts that require attention, namely 'pollution control' and 'pollution prevention'. Treating wastewater and its correct disposal to curtail the negative impact on environment is pollution control. Designing an industrial process to reduce/abate pollution and downstream treatments to mitigate environmental impact is pollution prevention. A lot of research and development and money has been spent for the first approach, and it is time that all industries and institutions try the second approach as there will be no hazardous problems and their required treatment to meet the national and international standards, e.g., standards set by the Pollution Control Board for release of industrial water into the environment.

When we move on to cleaner production, there is an increase in production efficiency due to efficient use of raw material, reduction in the use of natural resources, and lesser raw material conversion for larger quantity of end products leading to savings and economic benefits. This will also reduce waste treatment and disposal costs along with other allied benefits. The organization will stand steadily in the market in terms of both consumers and competitors. When cleaner production is adopted in the industry or manufacturing center, negative impacts on humans and nature are minimized in terms of toxic contents, wastewater, solid waste and emissions. The cost of waste management infrastructure and economics is reduced leading to environmental and economic benefits. It also prepares the industry for the future as it will be enabled to meet the national and global legislations and standards. On the social side, occupational safety and worker's health and transparency to consumers are addressed leading to brand building, reputation and customer loyalty.

When cleaner production is to be implemented in the industry, one requires to obtain management commitment and approval followed by the establishment of a team to study previous practices, and plan cleaner initiatives and implementation; the next step is to develop an environmental policy, objectives and targets followed by a Cleaner Production Assessment/Audit. The most widely used tool is the Cleaner Production Assessment (CPA) which comprises of a systemic analysis of the production process and its impact on environment. The CPA takes into account technology and management of processes as input and output (raw materials, processes, suppliers, products, emissions, etc.) and helps to find out the inefficient use of resources and neglect of waste management. The proposed cleaner production initiatives are evaluated in four ways, namely preliminary evaluation (viability of the options to pick the correct one), technical evaluation (potential impacts, trial runs, laboratory testing and safety concerns), economic evaluation (budget and cost feasibility) and environmental evaluation (positive and negative impacts and net reduction of toxics, waste and emissions).

6.2 Sustainability Reporting

Sustainability reporting is essential as the good work carried out in the factory or organization has to reach all the stake holders and other industries worldwide. It is a story that tells others about the risks and opportunities they face and the level of performance they have achieved. Many firms worldwide are adopting sustainability reporting through the Global Reporting Initiative (GRI) Sustainability Reporting Framework [114], which may be similar to other reporting frameworks. Sustainability reporting helps to improve the image of the organization, the employee retention and loyalty, to obtain low scores −0.6 in Kaplan-Zingales Index [115], gain access to external financing, increases efficiency and reduce waste production. Reporting also helps stake holders to understand the real value of the organization and its assets.

The GRI is a conglomerate of 3 series of standards, namely the universal standards, sector standards and the topic standards. Organizations can use the entire framework or segments to report any aspect they would prefer to convey to their stake holders. A revised version of GRI 101—Foundation has been released as GRI 1—Foundation 2021 along with guidelines to use the standard (4–62). Many global leaders have reported their contribution to sustainability. Dyestar's report shows the two-way sustainability strategy—cleaner, safer operations and innovating ecological solutions for reducing environmental impacts as per the principles of ISO 260000 Guidance on Social Responsibility and the United Nations Global Compact Principles [116]. In the case of Novozymes, a biotech company supplying enzymes, water and energy target improvement percentage in 2015 was 40 and 50%, respectively; the achievement in 2010 was 29 and 30%, respectively, showing that the improvement percentage paves the path to achieve the goal. The goal for CO_2 efficiency was 50% by 2015 and the achievement was in 2010 the improvement was 38% due to implementation of projects and purchase of electricity from wind turbines [117]. Lots of reports are available for all to understand the essence and core of company efforts toward sustainability and climate change (Table 5).

Table 5 Roadmap for sustainable management of natural resources

<table>
<tr><td colspan="5">Risks</td></tr>
<tr><td colspan="5">• High demand when compared to the resource supply – Freshwater, energy, land
• Over exploitation and declining resources - ground water table, fossil fuels, land toxicity
• Degradation of natural resources-surface & ground water quality, scarcity of fuels, output decrease
• Efficiency of Regulatory bodies low and passive - ETPs & CETPs, non use of assessment tools, no certification and regulations
• Industry readiness in real situation to attain regulatory standards
• Lack of good governance, transparency & accountability across the government sectors in implementation of scheme
• All ambitious programs or schemes can be an opportunity or risk</td></tr>
<tr><td colspan="5">SUSTAINABLE MANAGEMENT & USE OF NATURAL RESOURCES
-SUSTAINABLE DEVELOPMENT GOAL</td></tr>
<tr><td colspan="5">Remedies
• Establishing a baseline footprint/system by capturing the existing resource use and waste outputs
• Encouraing a transformation in the supply chain and convert to circular business model
• Integration of the pros and cons of sourcing, production and distribution into the companies operation profile and calculate profit & loss
• Adoption of a sustainable strategy for conservation of raw materials and preparation of a portfolio for materials using resources available by benchmarking bodies eg. Preferred Fibers and Materials Benchmark Insights (PFM), Textile Exchange
• Evaluation of the impact of sustainable strategy and sustainable reporting
• Building of brand image and customer loyalty</td></tr>
<tr><th>Clean technologies</th><th>Energy conservation</th><th>Water conservation</th><th>Land conservation</th><th>Circular economy</th></tr>
<tr>
<td>• Mechanisms & Assessment for industry to adopt clean technologies at a faster rate
• Guideline development for correct choice of technology for the industry
• Enhancing skills for implementation of the technology
• Communication & organization of regulations
• Better transparency & accountability to enable good governance
• Incentives for waste water recycling to reuse in production
• Creation of standards for water consumption
• Pilot testing and manual creation for use by all stake holders</td>
<td>• Fuel selection, combustion, handling & storage
• Steam generation, distribution & utilization
• Machine maintenance, renovation / replacement
• Process modification-energy conservation through software; use of foam technology, ultrasonic assisted wet processing, super critical dyeing etc.
• Waste heat recovery
• Alternate fuel source
• Use of high efficiency motors and high temperature grease according to motor type
• Replacement of undersize and over size motors and motors consuming high ‘no load power’
• Investigation of motor burning reason and correct rewinding
• Energy savings by adopting alternative techniques eg. drying & setting units, low MLR operations
• Use of unconventional renewable sources of energy
• Energy audit, instrument control & maintenance, waste heat records etc.</td>
<td>• Appreciation and gratitude of humans towards the water cycle
• System analysis and design of integrated water system for Water recycling eg. membrane technologies & nano filteration
• Direct reuse of low contaminated Water - cooling water from dyeing machine; process water from rinsing
• Waste water treatment for Zero Discharge
• Eliminate water leaks and reduce hose pipe use
• Water management requirement for suppliers – legal compliance & standards for water use & quality
• Water risk Assessment eg. Use of WWF Water risk filter
• Introduction of cleaner production program in value chain with external partners eg. Water PaCT/IFC, SWTI
• Identification and implementation of waste water recycling into the production processes
• Focus on issues, goals and actions towards water quantity, quality, circularity, collective action & communication
• Creation of regulatory & control measures in collaboration with global companies and local environmental bodies
• Building BATs and standards for water usage, discharge and pollution</td>
<td>• Regenerative farming-compost application on pasture, silvo pasture, , rotational grazing, conservation tillage, pasture cropping, planting windbreaks and buffers and creek restoration.
• Bio technology in agriculture-transgenic crops, biotechnology related processes and nutrients.
• Organic farming –crop rotation, companion planting, biological pest contol, use of natural insect killers and elemental synthetic substances
• Principles of Sustainable Agriculture – Efficient harvesting of sunlight, water utilization, Integrated nutrient & pest management, promotion of biodiversity in and around the agricultural land
• Agronomic sustainability – crop rotation, integrated pest management, use of multiple technologies and cultural practices, prevention of over farming and soil erosion.
• Sustainable technologies-vermin compost, Azolla cultivation. Bio gas slurry manure, multi-tier cropping, Pheromone and light trap systems for pest management (4-69)</td>
<td>• procuring lower-impact fibers
• increase the useful life of clothing
• Maintenance of clothing with reduced wash cycles
• use of biodegradable dyes, threads, and inks
• New & smart technologies for low water & energy usage
• Supplier commitment to sustainable materials
• SDG related certifications – Bluesign systems, OEKO-TEX certifications, HIGG Index, ZDHC, PaCT
• CE Input – prevention of banned materials into the circular value chain, Design to return unwanted used clothing into the fiber feedstock for the next production
• CE Process- support traceability & transparency as per policy requirements, create bill of substances, recovery of chemicals from production processes
• CE output- control and remediation of output streams – encourage water reuse, chemical recovery & valuable materials from waste & sludge
• Aim – zero waste and zero discharge</td>
</tr>
</table>

6.3 Roadmap for Sustainable Management of Natural Resources

The natural resources discussed here is water, energy and land. Optimum use and time for regeneration are important issues. When we look at the current trend in the natural resource consumption, there seem to be many risks involved that may have a severe impact on climate change. All industrial processes require raw material to perform their function and cater to the needs of the consumers. The Global Water Report 2020 states that the maximum financial impacts of water risks are five times higher (US$ 301 billion) when compared to the cost of tackling them (US$ 55 billion) [118]. This is true for all sectors except infrastructure and energy, showing that there is need for action. Further, the prediction is that the world water demand will increase by 55% by 2050 [119]. According to the International Energy Agency, the demand for electricity at the global level is growing faster than the renewable supply, leading to an increase in fossil fuel generation. Due to the economic recovery after COVID-19, the energy demand is set to grow to 5% in 2021 and 4% in 2022, putting the C02 emissions to a record level of 3.5% in 2021 and 4% in 2022 [120]. These facts show that there will be unprecedented use of natural resources to result in huge consequences on the climate as witnessed in the recent years. The circular economy has to swing into action to use and reuse raw materials and resources so that there will be lesser need for virgin materials. New technologies are to be implemented to obtain maximum benefits from minimal utilization of resources. SABIC [121, 122], a leading multiple business organization in Saudi Arabia, has devised floating photovoltaic systems. Solar fields are built on lakes to generate energy efficiently without overheating or using land resources. Further, their wind turbine blades are made of thermoplastic PET foam in combination of compounds to enable recycling of materials at the end of their service life. These examples show the use of clean technologies leading to circular economy.

Concluding Remarks

Consumers of today are conscious about the products they buy and the extent to which their purchase will impact the environment. Hence, supply chain traceability and transparency are of primary importance. By taking a closer look on the supply chain, manufacturers and retailers can appraise features causing threat to biodiversity, human well-being and climate, thereby making tangible decisions for future planning and target setting. Traceability will also provide well-required data that can be conveyed to consumers with regard to the impact of their products and sustainability. The textile and fashion industries have contributed to climate change that has expressed the havoc in terms of extreme weather events due to global warming. Manufacturing should focus more on sustainable processes that would nullify biodiversity and ecosystem losses by resource conservation and zero emissions leading to the reversing of climate change. Efficient use of natural resources coupled with sustainable choice of chemicals and clean technologies will result in secure work environment, thereby fulfilling the standard of respect of universal human rights.

Research in developing new material mixes and matrix with minimal or no impact on environment is the need of the hour. Substitution of conventional materials would have to serve both aesthetics and performance coupled with a positive social, environmental and ethical footprint. All these efforts will result in circular economy where all waste of the first generation manufacturing will become the natural resource of the second generation manufacturing cycle.

Zero waste and zero discharge should be the focus and new technologies, and research reports need to be carefully implemented to bring about conservation and preservation. COVID-19 has taught us many lessons along with patience and perseverance to lead a simple and joyful life. All stake holders in the supply chain have to plan every single move with sustainability as the focus and environmental impact as very minimal. Cleaner technologies will help in achieving the circular economy with huge considerations on the use of resources as they are scare and need time to regenerate. Renewable resources must be used for most industrial processes to make raw material and process efficient leading to a sustainable future.

To quote a few expressions on sustainable natural resources and conservation ….

> Let us pledge to collectively work toward conserving precious environment resources. Let us live in harmony with nature and keep our beloved Earth clean and green.—Narendra Modi [123]

> I believe in a sound, strong environmental policy that protects the health of our people and a wise stewardship of our nation's natural resources.—Ronald Regan [124]

> If conservation of natural resources goes wrong, nothing else will go right—M.S. Swaminathan [125]

References

1. United Nations (2014) The millennium development goals report 2014. https://www.un.org/millenniumgoals/2014%20MDG%20report/MDG%202014%20English%20web.pdf. Accessed 4 Oct 2021
2. United Nations (2021) Envision 2030: 17 goals to transform the world of persons with disabilities. https://www.un.org/development/desa/disabilities/envision2030.html. Accessed 4 Oct 2021
3. Sustainable Development Goals (2021) The sustainable development agenda. https://www.un.org/sustainabledevelopment/development-agenda/. Accessed 4 Oct 2021
4. United Nations (2021) Sustainable development report 2021. https://dashboards.sdgindex.org. Accessed 4 Oct 2021
5. Sustainable Development Report (2021) Chapters of the sustainable development report 2021. https://dashboards.sdgindex.org/chapters. Accessed 4 Oct 2021
6. Sustainable Development Report (2021) Rankings. https://dashboards.sdgindex.org/rankings. Accessed 4 Oct 2021
7. Sustainable Development Report (2021) Overall score. https://dashboards.sdgindex.org/map. Accessed 4 Oct 2021
8. Sustainable Development Report (2021) Country profiles. https://dashboards.sdgindex.org/profiles. Accessed 4 Oct 2021

9. Sustainable Development Report (2021) Highlighted countries. https://dashboards.sdgindex.org/explorer. Accessed 4 Oct 2021
10. SDG Academy (2021) 12 responsible consumption and production. https://sdgacademy.org/goal/responsible-consumption-and-production/. Accessed 4 Oct 2021
11. SDGs Today (2021) Ensure responsible consumption and production patterns. https://sdgstoday.org/sdg/responsible-consumption-and-production. Accessed 4 Oct 2021
12. SDG Tracker (2021) Sustainable development goal 12 ensure responsible consumption and production patterns. https://sdg-tracker.org/sustainable-consumption-production. Accessed 4 Oct 2021
13. Sustainable Development Report (2021) Downloads. https://dashboards.sdgindex.org/downloads. Accessed 4 Oct 2021
14. Sustainable Development Goals (2021) 12 responsible consumption and production-ensure responsible consumption and production patterns. https://www.un.org/sustainabledevelopment/wp-content/uploads/2020/07/E_infographics_12.pdf. Accessed 4 Oct 2021
15. Sustainable Development Goals (2021) 15 life on land. https://www.un.org/sustainabledevelopment/wp-content/uploads/2020/07/E_infographics_15.pdf. Accessed 4 Oct 2021
16. Igarape' Institute (2021) Mapping environmental crime in the Amazon. https://storymaps.arcgis.com/stories/7c11c5509a1f4258b225790f95311244. Accessed 4 Oct 2021
17. Sustainable Development (2017) New goals for a sustainable future. https://about.hm.com/content/dam/hmgroup/groupsite/documents/en/Digital%20Annual%20Report/2017/Annual%20Report%202017%20Sustainable%20development.pdf. Accessed 4 Oct 2021
18. SERI & Friends of Earth (2009) Overconsumption? Our use of the world's natural resources. https://friendsoftheearth.uk/sites/default/files/downloads/overconsumption.pdf. Accessed 7 Oct 2021
19. UN Environment Program (2018) Emissions gap report 2018. https://wedocs.unep.org/bitstream/handle/20.500.11822/26895/EGR2018_FullReport_EN.pdf?sequence=1&isAllowed=y. Accessed 10 Oct 2021
20. Youmatter (2020) Ecosystem: definition, examples, importance- all about ecosystems. https://youmatter.world/en/definition/ecosystem-definition-example/. Accessed 10 Oct 2021
21. Monbiot G (2017) How wolves change rivers. https://www.youtube.com/watch?v=ysa5OBhXz-Q&t=273s. Accessed 10 Oct 2021
22. Scitable (2014) Phenotype/phenotypes. https://www.nature.com/scitable/definition/phenotype-phenotypes-35/. Accessed 10 Oct 2021
23. Aakash Bjus (2021) What is species diversity? https://byjus.com/neet/why-is-species-diversity-important/. Accessed 10 Oct 2021
24. Youmatter (2020) Biodiversity definition: what is it, protection, loss and CSR commitments. https://youmatter.world/en/definition/definitions-biodiversity-what-is-it-definition-protection-loss-and-csr-commitments/. Accessed 12 Oct 2021
25. Bansard J, Schroder M (2021) The sustainable use of natural resources: the governance challenge. https://www.iisd.org/articles/sustainable-use-natural-resources-governance-challenge
26. Britannica (2021) Conceptual approaches to natural resource management. https://www.britannica.com/topic/natural-resource-management/Conceptual-approaches-to-natural-resource-management. Accessed 10 Oct 2021
27. Fibershed (2019) Climate beneficial wool. https://www.fibershed.com/programs/fiber-systems-research/climate-beneficial-wool/. Accessed 3 Feb 2019
28. Estil L (2014) Lani's Lana – fine Rambouillet Wool. https://www.lanislana.com/. Accessed 1 Feb 2019
29. Adams BB (2018) Regenerative fiber farming. http://www.ecofarmingdaily.com/restorative-fiber-farming/. Accessed 28 Jan 2019.
30. Marin Carbon Project (2018) What is carbon farming. https://www.marincarbonproject.org/carbon-farming. Accessed 28 Jan 2019
31. Olsson G (2015) Water and energy: threats and opportunities. IWA Publishing, London
32. Zhang Q, Wang S, Yang F, Yue P, Yao T, Wang W (2015) Characteristics of dew formation and distribution, and its contribution to the surface water budget in a semi-arid region in China. Boundary-Layer Meteorol 154:317–331. https://doi.org/10.1007/s10546-014-9971-x

33. Hanisch S, Lohrey C, Buerkert A (2015) Dewfall and its ecological significance in semi-arid coastal south-western Madagascar. J Arid Environ 121:24–31. https://doi.org/10.1016/j.jaridenv.2015.05.007
34. Jacobs AFG, Heusinkveld BG, Berkowicz SM (2002) A simple model for potential dewfall in an arid region. Atmos Res 64:285–295. https://doi.org/10.1016/S0169-8095(02)00099-6
35. Lan S, Hu C, Rao B, Wu L, Zhang D, Liu Y (2010) Non-rainfall water sources in the topsoil and their changes during formation of man-made algal crusts at the eastern edge of Qubqi Desert. Inner Mongolia Sci China Life Sci 53:1135–1141
36. Anonymous (2019) Definition of soil organic matter. http://karnet.up.wroc.pl/~weber/def2.htm. Accessed 30 Jan 2019
37. DeLonge MS, Ryals R, Silver WL (2013) A lifecycle model to evaluate carbon sequestration potential and greenhouse gas dynamics of managed Grasslands. ECOSYSTEMS 16:962–979. https://doi.org/10.1007/s10021-013-9660-5
38. Paustian K, Lehmann J, Ogle S, Reay D, Robertson GP, Smith P (2016) ‘Climate-smart’ soils: a new management paradigm for global agriculture. Nature 532:49–57
39. Poeplau C, Don A (2015) Carbon sequestration in agricultural soils via cultivation of cover crops—A meta-analysis. Agr Ecosyst Environ 200:33–41. https://doi.org/10.1016/j.agee.2014.10.024
40. Su Y, Wang J, Yang R, Yang X, Fan G (2015) Soil texture controls vegetation biomass and organic carbon storage in arid desert grassland in the middle of Hexi corridor region in Northwest China. SOIL RES 53:366–376. https://doi.org/10.1071/SR14207
41. Zhang J, Zhang Y, Downing A, Cheng J, Zhou X, Zhang B (2009) The influence of biological soil crusts on dew deposition in Gurbantunggut Desert. Northwestern China J Hydrol 379:220–228. https://doi.org/10.1016/j.jhydrol.2009.09.053
42. Amede T, Menza M, Awlachew SB (2011) Zai improves nutrient and water productivity in the Ethiopian Highlands. EXP AGR 47:7–20. https://doi.org/10.1017/S0014479710000803
43. Bekunda M, Sanginga N, Woomer PL (2010) Restoring soil fertility in sub-Sahara Africa. Adv Agron 108:183–236. https://doi.org/10.1016/S0065-2113(10)08004-1
44. Mollison B (1988) Permaculture: a designers manual. Tagari Publications, Tyalgum, Australia
45. Thygesen A, Oddershede J, Lilholt H, Thomsen AB, Ståhl K (2005) On the determination of crystallinity and cellulose content in plant fibres. Cellulose 12:563–576. https://doi.org/10.1007/s10570-005-9001-8
46. Chen H (2014) Biotechnology of lignocellulose. Theory and practice. Springer Verlag, Dordrecht, The Netherlands
47. Beton A, Dias D, Farrant L, Gibon T, Le Guern Y, Desaxce M, Perwueltz A, Boufateh I (2014) Environmental improvement potential of textiles (IMPRO-textiles). Luxembourg: Publications Office of the European Union
48. Thuriès L, Bastianelli D, Davrieux F, Bonnal L, Oliver R, Pansue M, Feller C (2005) Prediction by near infrared spectroscopy of the composition of plant raw materials from the organic fertiliser industry and of crop residues from tropical agrosystems. J Near Infrared Spec 13:187–199. https://doi.org/10.1255/jnirs.537
49. Peltre C, Thuriès L, Barthès B, Brunet D, Morvan T, Nicolardot B, Parnaudeau V, Houot S (2011) Near infrared reflectance spectroscopy: a tool to characterize the composition of different types of exogenous organic matter and their behaviour in soil. Soil Biol Biochem 43:197–205. https://doi.org/10.1016/j.soilbio.2010.09.036
50. Wikes S (2017) Growing value for wool growers – an economic feasibility study and new business model. http://www.fibershed.com/wp-content/uploads/2017/12/Fibershed-USDA-VAPG-Economic-Feasibility-Study-1.pdf. Accessed 28 Jan 2019
51. James C (2003) Global status of commercialized transgenic crops: 2003. https://www.isaaa.org/resources/publications/briefs/30/download/isaaa-brief-30-2003.pdf. Accessed 30 Jan 2019
52. James C (2005) Global status of commercialized biotech/GM crops: 2005. https://www.isaaa.org/resources/publications/briefs/34/download/isaaa-brief-34-2005.pdf. Accessed 30 Jan 2019

53. Carpenter JE, Gianesse LP (2001). Agricultural biotechnology: updated benefit estimates. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.178.3689&rep=rep1&type=pdf. Accessed 30 Jan 2019.
54. Gianesse LP, Sankula S (2003) The value of herbicides in US Crop production. http://www.ncfap.org/documents/FullText.pdf. Accessed 30 Jan 2019
55. Cantrell RG (2006) The role of biotechnology in improving the sustainability of cotton. https://cottontoday.cottoninc.com/wp-content/uploads/2016/08/BiotechnologyRole.pdf. Accessed 27 Jan 2019
56. Sankula S, Marmon G, Blumenthal E (2005) Biotechnology-derived crops planted in 2004 - impacts on US agriculture
57. Cattaneo MG, Yafuso C, Schmidt C, Huang C, Rahman M, Olson C, Ellers-Kirk C, Orr BJ, Marsh SE, Antilla L, Dutilleul P, Carriere Y (2006) Farm-scale evaluation of the impacts of transgenic cotton on biodiversity, pesticide use, and yield. Proc Natl Acad of Sci 103:7571–7576
58. Qaim M, Zilberman D (2003) Yield effects of genetically modified crops in developing countries. Science 299:900–902
59. Choudhary B, Gaur, K (2015) Biotech cotton in India, 2002–2014. https://www.isaaa.org/resources/publications/biotech_crop_profiles/bt_cotton_in_india-a_country_profile/download/bt_cotton_in_india-2002-2014.pdf. Accessed 30 Jan 2019
60. Fitt GP, Wakelyn PJ, Stewart JM, Roupakias D, Pages J, Giband M, Zafar Y, Hake K, James C (2004) Report of the second expert panel on biotechnology in cotton, International Cotton Advisory Committee (ICAC). DC, USA, Washington
61. Huang J, Rozelle S, Pray C, Wang Q (2001) Plant biotechnology in China. Science 295:674–678
62. Radhakrishnan S (2017) Sustainable cotton production. In: Sustainable fibres and textiles. Woodhead Publishing, pp 21–67.https://doi.org/10.1016/B978-0-08-102041-8.00002-0
63. USDA (2004) Statistics of fertilizers and pesticides. https://www.nass.usda.gov/Publications/Ag_Statistics/2004/04_ch14.pdf. Accessed 30 Jan 2019
64. OMARA (2016) Introduction to organic farming. http://www.omafra.gov.on.ca/english/crops/facts/09-077.htm. Accessed 31 Jan 2019
65. Dahiru YM, Tanko H (2018) The prospects of organic agriculture and yield improvement in the 21st century. IJIABR 3:40–48
66. Gold MV (2018) Organic production/organic food: information access tools. https://www.nal.usda.gov/afsic/organic-productionorganic-food-information-access-tools. Accessed 31 Jan 2019
67. FIOL (2017) The world of organic agriculture- Statistics and emerging trends 2017. https://shop.fibl.org/CHen/mwdownloads/download/link/id/785/?ref=1. Accessed 31 Jan 2019
68. Ton P (2004) The international market for organic cotton. In: Baier A (ed) 04 Cotton: A European Conference on Developing the Organic Cotton Market, Hamburg: 17. PAN-Germany
69. Klein RC (2006) Organic cotton market report, Spring. An in-depth look at a growing global market. Market Reports. Berkeley: Organic Exchange. http://www.organicexchange.org/marketreport.php. Accessed 31 Jan 2019
70. Lanting H, Raj DA, Sridhar K, Ambatipudi A, Brenchandran S (2005) Case study on organic versus conventional cotton in Karimnagar, Andhra Pradesh, India. In Hoddle MS (ed) Second Inter-Service Publication FHTET
71. Blaise D (2006) Yield, boll distribution and fibre quality of hybrid cotton (Gossypium hirsitum L.) as influenced by organic and modern methods of cultivation. J Agron Crop Sci 192:248–256
72. Blaise D, Rupa TR, Bonde AN (2004) Effect of organic and modern method of cotton cultivation on soil nutrient status. Commun Soil Sci Plant Anal 35:1247–1261
73. Clark MS, Horwath WR, Shennan C, Scow KM (1998) Changes in soil chemical properties resulting from organic and low-input farming practices. Agron J 90:662–671
74. Martini EA, Buyer JS, Bryant DC, Hartz TK, Denison RF (2004) Yield increases during the organic transition: Improving soil quality or increasing experience? Field Crop Res 86:255–266

75. Britannica (2021) Water resource. https://www.britannica.com/science/water-resource. Accessed 15 Oct 2021
76. Science Daily (2021) https://www.sciencedaily.com/terms/water_resources.htm. Accessed 15 Oct 2021
77. WWF (2020) The blue planet. https://wwf.panda.org/discover/knowledge_hub/teacher_resources/webfieldtrips/water/. Accessed 15 Oct 2021
78. BBC (1999) Sci/tech leaking earth could run dry. http://news.bbc.co.uk/2/hi/science/nature/442040.stm. Accessed 15 Oct 2021
79. Global Data Retail (2021) Poor water management in the apparel industry threatens the global water supply. https://www.retail-insight-network.com/comment/poor-water-management-global-supply/. Accessed 15 Oct 2021
80. BBC News (2015) Aral sea: the sea that dried up in 40 years. https://www.youtube.com/watch?v=5N-_69cWyKo. Accessed 15 Oct 2021
81. Osomtex (2021) Upcycled yarns and fabrics. https://www.osombrand.com/osomtex/ Accessed 15 Oct 2021
82. Textile Exchange (2018) Markets & brands. https://www.commonobjective.co/article/insider-series-ecoalf. Accessed 15 Oct 2021
83. Common Objective (2018) Innovation & trends – EVRNU: turning unwanted clothes into new fiber. https://www.commonobjective.co/article/evrnu-turning-unwanted-clothes-into-new-fibre. Accessed 21 Oct 2021
84. Common Objective (2018) Tintex textiles. https://www.commonobjective.co/tintex-textiles-s-a. Accessed 21 Oct 2021
85. Kiron MI (2021) Water management in textile industry-an overview. https://textilelearner.net/water-management-in-textile-industry/. Accessed 21 Oct 2021
86. We Are Spindye (2021) Environmental impact. https://spindye.com/environmental-impact/. Accessed 21 Oct 2021
87. Common Objective (2021) Sustainability issues, the issues: water. https://www.commonobjective.co/article/the-issues-water. Accessed 21 Oct 2021
88. Fbre2fashion (2018) Sustainable water management key issue in textile industry https://www.fibre2fashion.com/news/textile-news/sustainable-water-management-key-issue-in-textile-industry-241256-newsdetails.htm. Accessed 21 Oct 2021
89. Keating C (2020) Selfridges unveils vision to 'reinvent retail' as it commits to new sourcing standards. https://www.businessgreen.com/news/4019031/selfridges-unveils-vision-reinvent-retail-commits-sourcing-standards. Accessed 21 Oct 2021
90. The Conscious Club (2019) Water & clothing. https://www.theconsciouschallenge.org/ecologicalfootprintbibleoverview/water-clothing. Accessed 21 Oct 2021
91. CEO Water Mandate (2021) Six commitment areas. https://ceowatermandate.org/about/six-commitment-areas/. Accessed 21 Oct 2021
92. Water Action Hub (2021) Connect to sustainability efforts around the world. https://wateractionhub.org/. Accessed 21 Oct 2021
93. Balthazar L, Bilello RA, Lermaitre JM, Logue RW, Palmer WB, Senegal S, Solomon EW, Wooden H (1992) Natural energy sources. http://www.dnr.louisiana.gov/assets/TAD/education/ECEP/sources/b/b.htm. Accessed 23 Oct 2021
94. Nelson SA (2015) Energy resources. https://www.tulane.edu/~sanelson/eens1110/energy.htm. Accessed 23 Oct 2021
95. ENR (2021) Energy. https://www.enr.gov.nt.ca/en/state-environment/6-energy. Accessed 23 Oct 2021
96. WWF (2021) Natural resource. https://wwf.panda.org/discover/knowledge_hub/teacher_resources/webfieldtrips/natural_resources. Accessed 23 Oct 2021
97. Donev JMKC, et al. (2020) Energy education - natural resource. https://energyeducation.ca/encyclopedia/Natural_resource#:~:text=From%20an%20energy%20perspective%2C%20primary,must%20be%20discovered%20and%20extracted. Accessed 23 Oct 2021
98. Hanania J, Stenhouse K, Donev J (2015) Hubbert's peak. https://energyeducation.ca/encyclopedia/Hubbert%27s_peak. Accessed 23 Oct 2021

99. Khude P (2017) A review on energy management in textile industry. https://www.omicsonline.org/open-access/a-review-on-energy-management-in-textile-industry.php?aid=92916. Accessed 23 Oct 2021
100. United States Department of Energy (US DOE) (2004) Energy use, loss and opportunities analysis: U.S. manufacturing and mining. https://www.energy.gov/sites/prod/files/2013/11/f4/energy_use_loss_opportunities_analysis.pdfAccessed. Accessed 23 Oct 2021
101. Hasanbeigi A (2019) Energy management tools for textile & apparel companies. https://www.textilesustainability.com/blog/2019/10/15/energy-management-tools-for-textile-and-apparel-industry. Accessed 23 Oct 2021
102. Textile Exchange (2018) Fibers & materials platform. https://textileexchange.org/materials/. Accessed 1 Feb 2019
103. Textile Exchange (2018) Integrity and standards. https://textileexchange.org/integrity/. Accessed 1 Feb 2019
104. Organic Trade Association (2019) About OTA. https://www.ota.com/about. Accessed 1 Feb 2019
105. Organic Trade Association (2019) Organic standards. https://www.ota.com/organic Accessed 1 Feb 2019
106. IFOAM Organics International (2019) The organic guarantee system of IFOAM-Organics International. https://www.ifoam.bio/en/organic-guarantee-system-ifoam-organics-international. Accessed 1 Feb 2019
107. IFOAM Organics International (2019) IFOAM family of standards. https://www.ifoam.bio/en/ifoam. Accessed 1 Feb 2019
108. GOTS (2016) The standard. https://www.global-standard.org/the-standard.html. Accessed 1 Feb 2019
109. IVN (2019) About NATURTEXTIL IVN zertifiziert BEST. https://naturtextil.de/en/ivn-quality-seals/about-naturtextil-ivn-zertifiziert-best/. Accessed 2 Feb 2019
110. FAO (2019) Sustainability pathways – sustainability assessment of food and agricultural systems. http://www.fao.org/nr/sustainability/sustainability-assessments-safa/en/. Accessed 2 Feb 2019
111. Field to Market (2019) Field to market – the alliance for sustainable agriculture. https://fieldtomarket.org/. Accessed 2 Feb 2019
112. Field to Market (2019) Sustainability metrics. https://fieldtomarket.org/our-program/sustainability-metrics/. Accessed 2 Feb 2019
113. RISE (2011) RISE (Response-inducing Sustainability Evaluation) version 2.0. http://www.saiplatform.org/uploads/Modules/Library/What%20is%20RISE%202.pdf. Accessed 2 Feb 2019
114. Ecovadis (2021) What is sustainability reporting. https://ecovadis.com//glossary/sustainability-reporting/. Accessed 12 Oct 2021
115. Ycharts (2021) KZ index. https://ycharts.com/glossary/terms/kz_index#:~:text=The%20KZ%2DIndex%20(Kaplan%2D,difficulty%20financing%20their%20ongoing%20operations. Accessed 12 Oct 2021
116. Dyestar Group (2010) 2010 sustainability report. https://www.fibre2fashion.com/sustainability/pdf/dystar.pdf. Accessed 12 Oct 2021
117. Novozymes (2021) Financial & sustainability discussion. https://www.fibre2fashion.com/sustainability/pdf/Novozymes.pdf. Accessed 12 Oct 2021
118. CDP (2020) A wave of change: the role of companies in building a water-secure world. https://www.cdp.net/en/research/global-reports/global-water-report-2020?cid=1510992613&adgpid=58880714100&itemid=&targid=kwd-13874229455&mt=b&loc=1007810&ntwk=g&dev=c&dmod=&adp=&gclid=CjwKCAjwzt6LBhBeEiwAbPGOgQN8_mJKVADVWBQUA9u4DbQ2fXG1FJW1CFGOgaVca6uBEWQGGZnUzhoCPsMQAvD_BwE. Accessed 15 Oct 2021
119. Day A (2019) World water demand will increase by 55% by 2050. https://savethewater.org/water-demand-to-increase-55-globally-by-2050/?gclid=CjwKCAjwzt6LBhBeEiwAbPGOganm_-TK1FqDd_sRMPgSsv8_0N_hknHhVpYm2GV6X02LqPDfRW299hoCIewQAvD_BwE. Accessed 15 Oct 2021

120. IEA (2021) Global electricity demand is growing faster than renewable, driving strong increase in generation from fossil fuels. https://www.iea.org/news/global-electricity-demand-is-growing-faster-than-renewables-driving-strong-increase-in-generation-from-fossil-fuels. Accessed 15 Oct 2021
121. Sabic Collaboration Solutions (2021) Energy efficiency Collaboration – the power of tomorrow. https://www.sabic.com/en/collaboration/trend/energy-efficiency?gclid=CjwKCAjwzt6LBhBeEiwAbPGOgUYEsh8sfgAgtXAwCozXTXuZfMD6PIOddS5Sb9rRZ5Lb3VG7NU358xoCmPMQAvD_BwE. Accessed 15 Oct 2021
122. Sabic Collaboration Solutions (2021) More power for wind energy. https://www.sabic.com/en/collaboration/article/wind-energy. Accessed 15 Oct 2021
123. PM India (2021) Top quotes by Prime Minister Modi on environment. https://www.pmindia.gov.in/en/image-2015/top-quotes-by-prime-minister-modi-on-environment/. Accessed 15 Oct 2021
124. TodayINSCI (2021) Natural resource science quotes. https://www.google.com/search?sxsrf=AOaemvLslb4yhHZ71hCdnCJzVtXMqO459g:1635251986740&source=univ&tbm=isch&q=quotes+on+use+of+natural+resources+by+Indians&fir=mXFuftFTORoeRM%252Cm6WUv_pZflWKFM%252C_%253BGObycxz_xF4zNM%252Cm6WUv_pZflWKFM%252C_%253BKLXzi_jubupMOM%252Cod1iz9uVREZdwM%252C_%253BkODiGZhubPCHZM%252CG3ZGkknND4IaqM%252C_%253BM3U3GtwaxYsc_M%252CF2RZp7bPv8FGzM%252C_%253B7Wd44UQQcZehAM%252CwcsXdDCfHdb69M%252C_%253B2fNU870C4RTQFM%252CF2RZp7bPv8FGzM%252C_%253BoAsDHZ27A1M8_M%252CAFU7s56P4DhEUM%252C_%253BwkntmejEl6RRsM%252Co62jCY5wdFP7hM%252C_%253BssggSx4l4NxteM%252CF2RZp7bPv8FGzM%252C_&usg=AI4_-kRw-pij2IhBODhJS8c00xn63QrxQQ&sa=X&ved=2ahUKEwjp-aWujOjzAhVCzjgGHXyXA68Q7Al6BAgIEEg&biw=1366&bih=568&dpr=1. Accessed 22 Oct 2021
125. Azoquotes (2021) Top 25 Natural resources quotes. https://www.azquotes.com/quotes/topics/natural-resources.html. Accessed 20 Oct 2021