CHAPTER 10
SUSTAINABLE LANDSCAPING: THE FUTURE OF GREEN SPACES

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ABSTRACT

Sustainability is a new paradigm in landscaping that concerns with fulfilling the needs of population without diminishing the ability of future populations to meet their needs. Sustainable landscaping is concerned with the planning and design of outdoor spaces which include ecological, environmental, social and economic aspects of sustainability. These practices include water conservation, preventing erosion and soil degradation, minimizing air, soil and water pollution and reducing greenhouse gas emissions to protect the environment. Sustainable landscaping is a part of growing global effort in the landscaping industry to create aesthetically pleasing landscapes while improving and conserving the environment apart from saving money. It includes an appropriate design that fulfils functional, cost efficient, visually pleasing, eco-friendly and low maintenance needs of the community. The spatial dimension of these designs engages processes and relations between different land use patterns, ecosystems and biotopes at different scales over the time. Therefore, new technologies like xeriscaping, bio walls, phytoremediation, bio-aesthetic planning and permaculture have been developed to improve the urban ecosystems. But major challenge in this industry is how to design and renovate an environment or city to make it more sustainable to the extent possible. Hence, new approaches are needed to address the complex issues arising from increasing world population, depletion of resources and decreasing quality of human habitat.

Keywords: Eco-friendly**,** landscape design, native plants, sustainability, water conservation

Introduction

Industrial revolution along with a booming population rise and urbanization has become the main spotlight surrounding landscape architecture (Chen and Wu, 2009). Most of the Asian countries have witnessed up to 80% of their population migration to urban areas. These mass migrations witnessed a tremendous loss of biodiversity as forest land is cleared for residential purposes (Armas *et al*., 2014). Due to these transformations, neighboring rural landscapes and remote villages have been delegated to functional urban regions (FURs) and are slowly losing their cultural and heritage value. These patterns influence landscape architecture to be catered solely to urban spaces and to serve the metropolitan needs. Hence, in order to fulfill the environmental, household and recreational needs of the city dwellers sustainable landscaping is emerging as a viable alternative in urban ecosystems.

Sustainable landscaping refers to landscape practices that preserve our planet and environment without depleting and damaging natural resources like air, water and soil. It promotes practices that support and nurture all life forms and their habitats (Lier, 1998) present on the earth eco-system. Sustainable landscape designs describe a variety of outdoor landscapes that provides the ecological benefits required to meet the economic, social and ecological demands of both present and future generations (Wu, 2013). Sustainable landscaping encompasses a variety of practices that have developed in response to environmental issues and it includes practices that addresses major issues of renewable and non-renewable resources, emission of greenhouse gases that contribute to global climate change, air, water and soil quality (Cena, 1999). These practices are considered in every phase of landscaping, including designing, construction, implementation and management of residential and commercial landscapes. The main goals of sustainable landscape designs are to conserve water and energy, reduce waste and decrease runoff. In order to achieve these goals, the gardens designed should fulfill both short- and long-term goals in which short term goals consider water as a resource, value soil, preserve existing plants and conserve material resources whereas long term goals concerns about maintenance of all aspects of total plant care and cut down the inputs and maintenance costs. These sustainable landscape patterns can be distinguished into several types (Urban growth boundary, Ecological network and Green infrastructure and Ecological security pattern) depending on the environmental protection targets and regional development needs which are discussed hereunder-

i) Urban growth boundary (UGB): It ensures the protection of sustainable ecosystems in the context of rapid urbanization characterized by intensified habitat fragmentation (Huang *et al*., 2019).

ii) Ecological network (EN): This is a concept providing an operational approach for conserving biodiversity (Hofman *et al*., 2018).

iii) Green infrastructure (GI): It shows a vision of cost-effective, nature-based solution for ecosystem maintenance as well as social development (Matthews *et al*., 2015).

iv) Ecological security pattern (ESP): It provides an integrated focus on individual or coupled landscape elements which can protect and enhance regional ecosystem structures, functions and services (Peng *et al*., 2019).

Benefits Of Sustainable Landscapes:

Sustainable landscapes improve the quality of life by contributing to economic, environmental and social benefits which are discussed hereunder-

i) Environmental benefits:

- Enhance and protect ecosystems and biodiversity
- Reduces solid waste
- Improves water and air quality
- Conserve natural resources
- Provide seasonal interest
- Maintain local agro-climate
- Reduces environmental hazards viz., pollution and climate change, etc.

ii) Economic benefits:

- Reduces operating costs
- Enhance asset value and profits
- Optimize life-cycle economic performance
- Improve employee productivity and satisfaction

iii) Health and community benefits:

- Improve air, thermal and acoustic environments
- Enhance occupant comfort and health
- Minimize strain on local infrastructure
- Contribute to overall quality of life

Principles Of Sustainable Landscaping:

A master plan is essential to ensure that all work done on the property will blend into the desired final outcome. Landscape development is a long-term process, there is no need to develop entire lot at once where it becomes sustainable with the time. Because each landscape is unique, there are no hard and fast rules for design. However, certain basic design principles will be

followed to create an aesthetically pleasing and sustainable landscape. These guidelines will help beginners to create a functional landscape. The standard landscape design principles include:

1. Simplicity: Landscapes that lack simplicity can look chaotic and do not create a sense of peace. Simplicity in a landscape can be physical, visual or both. Physical simplicity refers to a design that consists of simple lines either straight or gently curved with no complex geometric shapes or patterns. Visual simplicity is achieved when plants are arranged to appear as a single unit. For example, you can group three or more plants of the same species to create one visual mass.

2. Rhythm and line: Continuity and integration of different elements into a landscape affect rhythm and line. Effective use of repetition can direct the eye or a person through the landscape and create a sense of unity among different spaces.

3. Balance: The two common types of balance in landscapes are symmetrical and asymmetrical. Symmetrical balance is most common in formal landscapes. These landscapes have an obvious central axis and everything on one side is duplicated or mirrored on the other side. Asymmetrical balance uses different objects on each side of a discrete axis, but the end is a similar visual mass on both sides. Asymmetrical designs are well suited for home landscapes.

4. Proportion: This principle refers to the size relationship between various elements within a landscape. The major relationships to consider are plants to buildings, plants to other plants, and plants to people which changes over time as the plants grow. To achieve correct proportion, always design the landscapes based on the mature height and spread of the plants. Although plants might be a little out of scale when they are young, they will grow into proportion with other objects in the landscape.

5. Focal point: Focal points is the center of attraction in any landscape design which give the eye a place to rest when viewing the landscape as a whole. A focal point might be a plant specimen, garden accessory or water feature. The front door is an example of a focal point in the public area. Both the public and private use areas should have a focal point. If the area is large and divided into a number of smaller spaces, multiple focal points can be added.

Apart from the above, additionally few more principles such as aesthetic, functional and environmental principles (Rodie and Streich, 2009) are to be followed to make the landscape design more reliable, which are discussed here under subheads-

Aesthetic design Principles: Many design principles typically are reflected in a well-designed landscape. Although sustainable landscapes may appear more natural and less manicured, they still rely on all of the standard

design principles to create a visually appealing combination of plants and materials. Aesthetic principles including accent, contrast, harmony, repetition and unity ensure the design is attractive, visually compatible and has a sense of fit with the surrounding landscape.

Functional design principles: They dictate whether the design will meet certain health and safety criteria. For example, drainage must be routed away from the foundation of a home, sidewalks and outdoor spaces should be sized appropriately for homeowner and visitors use and landscapes should include areas dedicated to private, public and utility needs.

Environmental design principles: It is the third category of design principles that focus on enhancement of landscape microclimate through channeling or screening winds and shading structures while providing for winter sun exposure and increasing or decreasing humidity through adjustment in air movement. These principles also focus to increase biodiversity, reduce resource inputs and resource wastage along with maximization and reuse of resources.

Components Of Sustainable Landscapes:

1. Water quality: A sustainable landscaping approach would treat water as a valuable resource with proper design and plant selection. The need for irrigation can be reduced or eliminated. Furthermore, rainwater harvesting systems can be followed to capture storm water on site and use it for irrigation.

2. Soil quality: Soils are typically the most undervalued resource in landscapes. Soil quality and characteristics significantly affect the growth and health of plants. Compacted soil leads to problems such as restricted plant growth, erosion, runoff and flooding. Runoff caused by compacted soils is one of the main sources of water pollution. Hence, soil correction should be a major consideration in landscape installation.

3. Air quality: It is an important concern in any landscape design. Air quality depends on the systems designed to eliminate pollution from entering the environment and also ensure that a sustainable landscape not only eliminate new pollutants, but can also remove existing toxins. This can be achieved by planting trees which not only absorb air pollutants, but they should also remove CO_2 from the atmosphere.

4. Plants: A sustainable landscaping approach would assess the existing plant material and preserve native plants. Invasive, non-native plants should be removed and replaced with a more appropriate choice.

5. Energy system: Sustainable landscape approaches would reduce yard waste by selecting appropriately sized plants and reusing and recycling the construction waste. Composting can be integrated into a residential back yard garden for kitchen and yard or a regionals solid waste programme aimed at reducing landfill while providing organic matter for city or park sites.

Furthermore, an effective sustainable design also includes recycling of construction waste (paving materials, concrete materials and mulches) by careful selection of building materials and using locally sourced materials whenever possible.

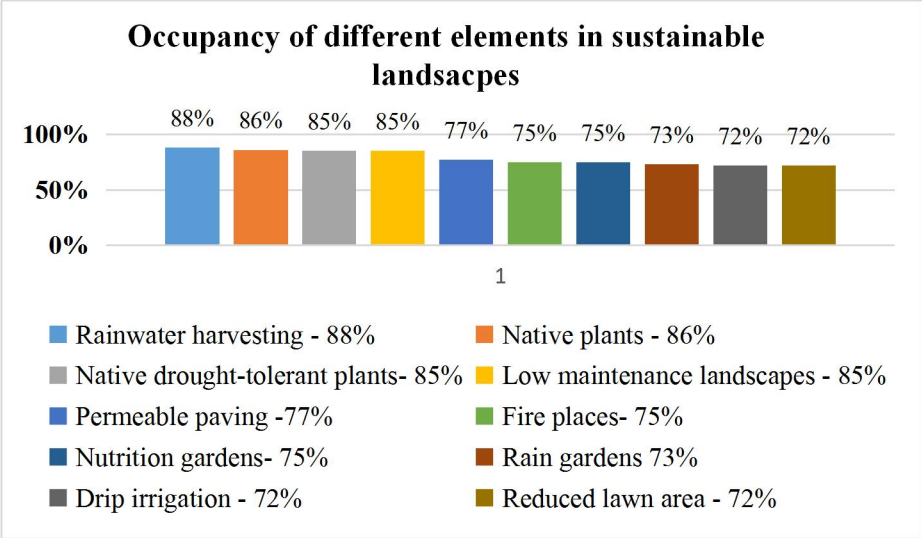

Fig 1. Occupancy of different elements in a sustainable landscape design as suggested by American society of landscape architects (ASLA) (Sharath and Peter, 2019)

Strategies For Developing A Sustainable Landscape Plan:

A sustainable landscape can be either formal or informal and sometimes leading from simple to complex design. Consider the principles of sustainability while setting up a smooth functioning ecosystem that makes minimal demands and creates minimal problems. Always maintain harmony with the local environment and carefully choose the inputs and outputs for long-term management by considering both on-site effects and off-site effects. The key ideas that make sustainable landscaping work are simple and easy to put into practice with minimal maintenance needs. Activities that can help to support more sustainable and climate appropriate landscapes include sound planning of the layout, selection of native plant species, establishment of kitchen garden for production of organic fruits and vegetables, water conservation and light management with minimal inputs, which are discussed below:

1. Plan and design: It is the foremost important step in developing a sustainable landscape plan. Conduct the site analysis to identify unique traits of the location such as ground slope, soil type, available soil moisture, light

conditions (sun light and shade duration and direction) and air movement. After site analysis, create a draft of the landscape plan by joining together all the components of the garden. In the next step, starting with a bubble diagram move through field measurements on a base sheet and end with a concept plan which is termed as conceptual design. The basic steps in design process include 1) conducting a site inventory and site analysis**,** 2) determining the needs of client**,** 3) creating functional diagrams, 4) developing conceptual design plans and 5) drawing a final design plan.

Site inventory: Landscape design process begins with a site inventory of soil type, drainage pattern, climate conditions and existing vegetation. This is a critical step for both plant selection and placement besides allocating space for family activities. The next step is to make a list of requirements of a client that will determine how the yard and landscape will be used. The site and client analysis will also help to establish a theme for the form and style of the garden. The functional diagram is then used to locate the activity spaces on the site and from this diagram a conceptual plan is developed. The last step is a final design that includes all the hardscape and planting details to be executed on a site.

Site analysis: The primary goal of the site analysis is to determine the activities to be undertaken to resolve problems and identify opportunities for locating new features. There are typical issues for majority of the sites that should be addressed during site analysis. The notes on the site analysis should take into consideration all these points, in addition to selection of a location on a site to create a focal point through either planting of specimen plant or highlighting by placing a fountain or other hardscape feature.

Site inventory and analysis are important for making decisions and developing the best feasible design for the site and the client. The site inventory is simply a list of all existing conditions and the site analysis is a judgment about the proposed activities (such as requirement of composting yard, pergola above a walkway etc.) to achieve the desired goals.

Design process for conducting site inventory and site analysis includes-

1. Carefully understand the site for plant selection for different locations
2. Remember to consider and incorporate the clients requirements
3. Try to develop a form or style theme to help determine shapes and organize spaces
4. Create and link spaces by designating activity areas and linking these with other features
5. Consider the functional aspect of existing and proposed plantation
6. Highlight important points such as transition areas and focal points
7. Pay attention to detail for the material make, colour and surface texture
8. Consider issues regarding maintenance of plants and other features
9. Should follow sustainable landscape design practices

2. Soil condition:

Healthy soil is an important foundation for every landscape. Aspects of soil composition, slope and need for amendments must be considered. Characteristics of the soil can help to determine the best choice of plants and irrigation systems for the landscape.

3. Regional climate:

Each region is distinguished by a set of climatic factors, including temperature (ranges and cycles), precipitation (amount and patterns), wind direction and strength, number of sunny days and seasonal changes in sun directions and humidity. All these factors eventually affect the size, location and orientation of all outdoor spaces and use areas. Also, while choosing the landscape material, it is advisable to opt for regional material which can able to bear the regional climate in order to harvest long lasting effects. Regional climate fit is an important factor which must be taken into consideration when designing a landscape project as it determines worthiness of the landscape in a particular location.

4. Plant selection:

Plants and vegetative cover play an enormous role in sustainable landscape and can even impact global climate change. Proper selection criteria must be applied when selecting vegetation.

Selection of indigenous plant species:

Selection of native trees and shrubs will add to natural beauty of the landscape. The plants will adapt and establish themselves relatively early compared to the exotic plantations that generally fail to survive or grow very slowly. The plants selected should be insect and disease resistant in order to avoid the pesticide usage. By planting shady trees at west or south west orientation (subjected to availability of space), the solar heat gain inside the building can be reduced. But before this, consider the plants ability to bear the environmental factor such as degree of sun or shade and wind. Always choose plants according to their functional capabilities such as degree of shading, wind breaking, visual screening or framing, erosion and sedimentation control. Aesthetic considerations are to be achieved by following landscape principles such as balance and rhythm depending on the type of landscape whether it is formal or informal. The ultimate secret of any ideal landscape is putting the right plant in the right place to ensure that the plants will be healthy, grow well and need a minimum care.

Plant suggestion for sustainable landscaping:

Trees for checking the pollution: Plants are very effective in controlling levels of pollution. They absorb harmful gases like carbon dioxide that are associated with urban heat islands. They also reduce the levels of other

pollutants, especially from automobiles. Buffer zones planted with trees are used for separating industrial areas from residential areas. In the process of plant selection, it is necessary to choose the plants according to the degree of pollution tolerance and the main function of the plant, especially the selection of trees should be more cautious. Industries are the major source of pollution, hence, in such areas, deciduous trees or trees having thick, shiny leaves will be more successful. Eg: *Morus sp*, *Poplar hybrida*, *Plumeria acutifolia*, *Ficus infectoria*, *Azadirachta indica*, etc.

Shrubs: Rhododendron, safflower, French holly, Lagerstroemia, Hibiscus, Pyracantha, *Euonymus japonicus*, *Pleurotus ostreatus*, *Pleurotus sylvestris*, etc.

Creepers: *Antigonon leptopus*, *Aristolochia elegans*, *Bougainvillea sp*, *Clitoria ternatea*, *Ficus repens*, etc.

Limit the size of lawn:
In a landscape design, turf occupies 25-30% of the total area. Though it is attractive and useful in erosion control, turf is not considered to be a sustainable option in landscaping as it demands for large supplements of water, labor and often chemicals to keep them healthy. Therefore, by reducing the usage of turf in a landscape, we can curtail the requirement of inputs for maintaining the garden.
Establishment of kitchen and herbal garden: A small kitchen or herbal garden at a residence will ensure availability of fresh seasonal vegetables and herbs for the family members. Some fruit trees like guava, papaya, peach, lemon and kinnow could be planted ensuring proper sunlight orientation and space for lateral spread of fruit plants.

5. **Mulching:** The soil around the tree berms can be conserved by covering the exposed soil surface with loose paddy straw or naturally shed leaf litter. These will add natural colour to bare soil and also prevent erosion and compaction of soil by avoiding direct impact of rainfall. Mulches will regulate the temperature and allow some of the rainwater to percolate therby avoiding water runoff. Mulching also enhances soil fertility by adding organic matter, insulate plant roots, reduce weeds and minimize water loss. It is advisable to use 2-3 inches of organic mulch uniformly spread around the plant which should be replaced every year.

6. Composting: It would be a best option to include a composting yard in a garden that will likely generate sufficient amount of bio-degradable plant litter. Composting done at home will ensure surplus availability of rich organic matter that can be utilized during different season or as per the plant

requirement. Grass-cycling is the natural recycling of grass by leaving grass clippings (thatch) not more than ½ inch over the lawn after mowing. The accumulated thatch decomposes quickly and releases valuable nutrients back into the soil, reducing water and fertilizer usage as well as maintenance costs.

7. Water conservation: Landscape plants need short-term irrigation following planting until they establish new roots in the soil. The choice of irrigation systems and techniques has great impact on the efficiency of water use in sustainable landscapes. The amount of water applied to landscapes can be divided into three levels of usage. The first level is water needed to meet baseline physiological needs of plants. The second level is water needed to compensate for system and there is no uniformity that all the plants receive the same level of water (particularly in turf). And the third is water applied in excess of that needed by plants or for system uniformity, which is potentially conservable. Installation of permeable pavement in place of concrete or asphalt in landscapes allows water to flow into the ground which can be collected to re-use in gardening. An effective and sustainable landscape designs minimize water usage and maintenance cost which can be achieved through installation of drip irrigation system or construction of underground water reservoir tank for rain water harvesting and using tertiary water for landscaping.

Rain water harvesting: This technique is domestically followed in portable and non-portable landscapes. The portable systems are adopted in household uses and non-portable uses for landscape purpose which can be divided into large scale (parks, schools, commercial plots) and small scale (residential landscapes). A custom-made water storage reservoir measuring 18 ft x 6 ft x 7 ft, connected with a terrace downspout has the potential to store 21,500 liters of water during rainy season from a roof area of 2000 sq ft. Accumulated water from the reservoir is pumped out with motor and can be utilized for irrigation, flushing and washing vehicles etc.

Drip irrigation: Adoption of **s**urface drip irrigation and sub-surface drip irrigation in commercial landscapes reduces the water consumption by at least 70% (Smith and Zeder, 2013).

Grassed swales: These are grassy depressions in the ground designed to collect storm water runoff from streets, driveways, rooftops and parking lots. Two general types of grassed swales are 1) a dry swale, which provides water quality benefits by facilitating storm water infiltration, and 2) a wet swale, which uses residence time and natural growth to treat stormwater prior to discharge to a downstream surface water body.

Using tertiary water for landscaping: Recycled water is highly treated wastewater from various sources such as domestic sewage, industrial wastewater and storm water runoff. In this, the water will be purified through three levels of treatment including filtration and disinfection. This recycled

water can be used for landscapes, agricultural irrigation, fish ponds, groundwater recharge and in fountains and recreational lakes.

8. Creating habitat for wildlife: Even in the smallest space in house located in an urban locality, a habitat for birds, butterflies, bees and squirrels can be created over terrace by placing different potted plant species, climbers and fragrant shrubs to encourage the visit of birds and pollinators that provide them shelter and add an element of charm in a limited and concrete landscapes.

9. Pollution prevention: Pollution prevention approaches can be applied to all pollution- generating activities in each and every step of designing process by applying proper remediation measures like planting pollution tolerant trees to completely remediate or control the pollutants from the polluted sites. These practices must be able to preserve wetlands, ground water sources and other critical ecosystems on the biosphere.

10. Landscape lighting: It would be a best sustainable practice to harvest natural available sunlight that will ensure bright natural lighting in residential or commercial buildings. Solar panels are being installed over house rooftop to harvest naturally available sunlight into clean electricity. Using energy efficient lighting columns such as compact fluorescent lamps and LED lamps being operated by renewable energy like solar energy, wind energy and hydro power supports both economic and ecological dimension as clean energy is produced by cutting down the non-renewable energy sources. Using timers or sensors will turn off luminaries when daylight adequately illuminates a space. Organic light-emitting diodes are highly efficient and offer long-lived natural light. These technologies can contribute to reduction in energy consumption which translated to reduced cost and pollution.

11. Minimizing the maintenance costs: The ultimate motto of any sustainable design is to cut down the maintenance costs by developing a design which can last for years with minimal maintenance. By building a landscape that needs little care, adopting organic methods that do not use harsh chemicals and using hand tools instead of power equipment makes sustainable landscape to be a place of peace, purity and productivity.

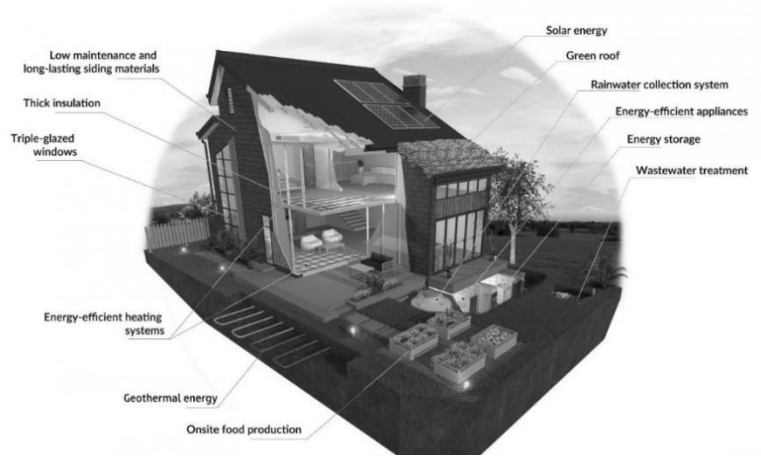

Fig 2. Layout of a sustainable house landscape

Recent Advances In Sustainable Landscape Industry:

1. Xeriscaping:

Xeriscaping is landscaping with slow-growing, drought tolerant native plant species to conserve water and reduce maintenance costs. Xeriscape incorporates water conserving principles like planning and designing of garden based on variation in soil moisture, installation of efficient micro-irrigation systems, use of compost and mulch material to conserve moisture, need-based addition of soil amendments, planting of appropriate species of turf, cacti and succulents. It is a water-efficient landscaping that aims to protect the water resources and environment by cutting down the supplemental water requirements (Cetin *et al*., 2018) and focuses on creating drought-resistant landscapes. Although xeriscaping is mostly used in arid regions, its principles can be used in any region to help conserve water.

2. Bio-aesthetic planning:

Bio-aesthetic planning can be defined as a conscious plan of the flora (plants) and fauna (Animals) with the objective of beautifying the rural and countryside areas. It can play an important role in environmental amelioration of urban and industrial areas along with their beautification. Major sites for bio-aesthetic planning include both public and private sites in rural areas which can be planted using native and indigenous strata for improving the local environment, attracting biodiversity beyond increasing aesthetics. Butterfly gardens are also a part of bio-aesthetic planning aiming to preserve different species of butterflies. It focuses on creating a landscape with different ornamental plants that will provide a suitable environment for butterflies to thrive and reproduce.

3. Ecotourism:

It involves creation of geo parks to instill ecotourism and restore historical and cultural integrity of a site (Harmanescu, 2014). Sustainable landscape patterns emphasize the coupling of spatial patterns, social-ecological processes and ecosystem services in conceptual intersection of landscape ecology and landscape sustainability. Furthermore, sustainable landscape patterns are constructed through taking regional and socio-ecological elements into account which addresses practical needs of achieving multiple sustainable development goals in current spatial planning. Identification, design and development of more functional sustainable landscape patterns will be key for supporting future landscape planning (Peng *et al*., 2021).

4. Phytoremediation:

Phytoremediation is an innovative and eco-friendly technique through which contaminated substrates are ameliorated by growing plants that have the capability to remove the contaminants. Phytoremediation of heavy metals can be achieved through processes such as phyto-stabilization, phytoextraction, phytovolatilization and rhizo-filtration. The key factor for successful phytoremediation is the identification of a plant that is tolerant and suitable for the specific area and local agro-climate. Use of ornamental plants for remediation of a contaminated environment would also change the landscape for ecotourism as they are not edible, the risk of contaminants entering the food chain is reduced and generating additional income including additional employment opportunities as well.

Some ornamental plants with stress tolerance ability:

Air cleaning		*Syngonium podophyllum, Dracaena sanderiana, Chlorophytum comosum, Ficus microcarpa, Dendranthema morifolium, Spathiphyllum wallisii and Aglaonema crispum, etc.*
Salt tolerance		*Plumbago auriculata, Caryopteris cladonensis, Callistemon laevis and Pavonia lasiopetala, etc.*
Drought tolerance		*Gaillardia pulchella, Rosa mellandina, Echinacea purpurea, etc.*

Table 1. Metal tolerance and remediation ability of ornamental strata

S. No.	Species	Remediated metal	Method
1.	*Azadirachta indica*	Pb	Accumulation
2.	*Calendula officinalis*	Cr	Translocation
3.	*Canna indica*	K and Ca	Accumulation
4.	*Eucalyptus camaldulensis*	Cd	Translocation
		Pb	Accumulation
5.	Garland Daisy (*Chrysanthemum coronarium*)	Zn, Pb, Ni, Cr, Cu and Cd	Accumulation
6.	*Gaillardia aristata*	Petroleum hydrocarbon (TPH)	Accumulation
7.	Sun flower (*Helianthus annuus*)	Pb	Stabilization
		Cd	Stabilization
		Cu	Translocation
		Zn^{2+}	Stabilization
8.	*Tagetes erecta*	Cr, Ni and Pb	Translocation
9.	*Vetiveria zizanioides*	Zn from water	Accumulation
		Cr	Translocation
		Ni, Pb, Co and Hg	Stabilization
10.	*Zinnia hybrida*	Petroleum hydrocarbon (TPH)	Accumulation

5. Bioretention cells:

Bioretention is a terrestrial-based, water quality and quantity control practice using the chemical, biological and physical properties of plants, microbes and soils for removal of pollutants from storm water. Some of the processes that

may take place in a bioretention cell include: sedimentation, adsorption, filtration, volatilization, ion exchange, decomposition, phytoremediation, bioremediation and storage capacity which can successfully contribute to sustainability in landscapes.

6. Portable landscapes:

To solve the problems of land constraint in urban areas and increasing demand for green spaces per unit area, it is possible to apply some specific methods for forming micro-landscapes. It involves the inclusion of vertical gardening with climbing plants, installation of portable gardens, hanging gardening in decorative vases and green islands in the pavement. Their success lies in the placement and composition which can be easily changed depending on the purpose. Portable gardens with the changing composition bring variety to those places where there is no scope for permanent landscaping. For hanging gardening, climbing plants can be used in the boxes mounted on vertical fence of buildings. The industrial urban landscapes can adopt fast-growing trees and shrubs, which should be planted in sufficiently dense planters which can be transported to area of interest.

7. Vertical gardening:

Vertical green structures (VGS) emerged as nature-based solution under limiting land areas in urban eco-systems. The main theme of vertical walls is exploitation in urbanization and fulfilling the needs to limit both land consumption and vegetation loss. A living wall is a system where plants and planting media are placed on the vertical surface of exterior walls. These structures can provide several ecosystem services like air purification, biodiversity enhancement, noise reduction, economic and environmental sustainability. A green facade is a system in which plants directly climb the walls and can reduce exterior temperatures by an average of 9-15^{o}C. Green facades contribute to the promotion of quality of life and well-being, ecological preservation, promotion of biodiversity, aesthetic enhancement and promotion of recreational uses (Susorova, 2015).

8. Soil conditioners or Hydrogels

Hydrogels made of polyacrylamide (a hydrophilic polymer) are an alternative approach in the form of soil conditioners. They help in reducing soil erosion, improving water retention capacity of soil, decreases high infiltration rates, prevents fertilizer and pesticide runoffs and reduces evaporation rates in irrigated lands. Soils that are amended with hydrogel show higher water retention. Hydrogel can act as a water reservoir for plants and it slowly supply micro and macro nutrients to enrich the soil. Its degradation products can be engineered to improve the nutrient content of the soil, and thus promote the growth of symbiotic organisms in the soil. Integrating innovative solutions

with environmental-friendly hydrogels in the coming decades will contribute to the pursuit of achieving sustainable development goals.

9. Edible landscaping through permaculture:

The term permaculture is introduced in 1978 by Bill Morisson and David Holmgrin. Permaculture is a collection of techniques for designing sustainable communities in a mix of old traditional techniques refined with new knowledge and technology. Permaculture is a technique for producing food that can be used on a small scale by individuals or families to improve their food security and by institutions to have a positive impact on their environment and provide food and other necessities. It is an integrated, multidimensional and creative design response to a world of declining energy and resource availability. Permaculture involves using renewable resources and services, production with no trace or recyclable waste along with valuing diversity.

Table: 2. Salient developments in sustainable landscape industry

S. No.	Concept	Purpose	Salient findings	Reference
1.	Xeriscaping	Water conservation	Adoption of xeriscaping as sustainable landscape approach can support rationalizing water consumption by 41% besides providing thermal reduction, economic and environmental benefits.	Ismaeil and Sobaih, 2022
2.	Smart solar panel umbrella system	Energy conservation	Smart solar panel umbrella system consists of automatic solar module and a raindrop sensor powered by 32-bit microcontroller which operates automatically when the weather changes and maintain high power conversion efficiency of 19.61% of the solar cell. It can be a viable option for landscape lighting to save the fuel energy and contribute in the realization of carbon	Liu et al., 2022

			neutrality.	
3.	Hydrogels	Water conservation	Application of hydrogel under water scarce conditions improve soil properties, increases water holding capacity of the soil, improves irrigation efficiency and increases the growth of various floriculture crops.	Nivya and Keerthishankar, 2022
4.	Rain garden	Erosion control	Rain gardens reduces volume of rainwater flow and prevent erosion, remove heavy metals and hydrocarbons from storm water and recharge ground water.	Sharma and Malaviya, 2021
5.	Terrace garden	Climate control	Ornamental terrace garden not only provide recreation and aesthetic view, but also moderates and stabilizes the ceiling temperatures and reduces it by about 2-3°C in winter months and 5-7°C in hot summers.	Chidambaram et al., 2020
6.	Green walls	Water conservation	Green walls decrease the runoff by more than half (i.e., 55%) demonstrating the effectiveness of green walls as a component in stormwater management.	Lau and Mah, 2018
7.	Xeriscaping	Water conservation	xeriscape in Mediterranean conditions could save 57.24% of the construction costs and 54.91% in annual maintenance costs. It also contributes to ecology by providing	Cetin et al., 2018

			water savings, reducing chemical use and preventing soil pollution.	
8.	Swales	Erosion control	Swales planted with grass and macrophytes having deeper root system are capable of retaining soil particles and also reduces the concentration of trace elements (such as lead, zinc and copper) by 17-45%.	Leroy et al., 2016
9.	Permeable plastic pavement	Sustainable city planning	Permeable plastic pavement (4-6% of granular recycled plastic) is a sustainable alternative for developing more cleaner and sustainable cities. It reduces plastic volume, captures rainfall and provides sustainability through decreased energy use, cooler city streets, cleaner air and thereby rising property values.	Cetin, 2015
10.	Green walls	Urban planning	Green walls absorb heat from the air, lower both indoor and outdoor temperatures, improve indoor air quality beyond beautifying the space. They hold or slows rainwater and also provide food and shelter for wildlife.	Timur and Karaca, 2013
11.	Greenways or Urban corridors	Sustainable benefits	Greenways are open passages created along the canals, riversides or scenic roads planted with vegetation for recreational uses. These urban corridors	Salic, 2013

			create open spaces for public access for green spaces and also protect natural resources (habitat, wildlife) by balancing between the air pollution and excessive heat changes eventually improving urban climate.	
12.	Pedestrian tree plantings	Climate control	Trees planted along pedestrian walks improve local microclimate by reducing urban heat island effect. Trees purify the air by diluting and absorbing pollutants and depositing airborne particles on their leaves.	Ebru, 2013
13.	Xeriscaping	Water conservation	Urban xeriscaping has the potential to reduce urban water use, urban temperatures and outdoor thermal discomfort.	Chow and Brazel, 2012
14.	Bioretention	Storm water conservation	Bioretention swale systems harvests stormwater, filters it through an engineered soil media and delivers into a storage facility for reuse. Bioretention swales can improve biodiversity above the ground compared to the conventional green spaces	Kazemi et al., 2011
15.	Composted dairy manure	Soil enrichment	Addition of composted dairy manure solids to soils can improve soil properties and enhance plant growth in residential landscapes.	Loper et al., 2010

16.	Bioindicators	Biological control	Bioindicators (living organisms) have the potential to optimize different farming systems, input practices, new crop rotations and also influence policies governing landscape management, urban and industrial areas, landscape reclamation and transformation.	Paoletti, 1999

Conclusion:

Sustainability paradigm has emerged from the global issues. New approaches are needed to address the complex issues arising from increasing world population, depletion of resources and decreasing quality of human habitat. Therefore, that future studies on all aspects of sustainability (e.g., environmental, social, economic, human and policy) need to follow the integrated approach so that the results could be made more compatible. By connecting people to their environment, it becomes part of their identity, and it gives motive to protect the ecosystem. Multidisciplinary policies are essential to cultivate sustainable landscape design within multiple realms, making their implementation a favorable way to design urban landscapes in a sustainable fashion. However, sustainable landscape patterns are still a novel field of research, further contributions are required in order to build a more complete framework linking theory with practice

REFERENCES

Armas, I., Osaci-Costache, G., & Brasoveanu, L. (2014). Forest landscape history using Diachronic cartography and GIS. Planning and Designing Sustainable and Resilient Landscapes. Springer Geography. Springer, Dordrecht. pp: 73-86.

Cena, F. (1999). The farm and rural community as economic systems. In: Golley, F.B., Bellot, J. (Eds.), Rural Planning from an Environmental Systems Perspective. Springer, New York, pp. 229-286.

Cetin, M. (2015). Consideration of permeable pavement in landscape architecture. Journal of Environmental Protection and Ecology, 16(1): 385-392.

Cetin, N., Mansuroglu, S., & Onac, A. K. (2018). Xeriscaping feasibility as an urban adaptation method for global warming. Polish Journal of Environmental Studies, 27(3): 1009-1018.

Chen, X. & Wu, J. (2009) Sustainable landscape architecture: implications of the Chinese philosophy of "unity of man with nature" and beyond. Landscape Ecology, 24: 1015–1026.

Chidambaram, C., Surabhi, S. N., Pranjali, V. and Kumar, S. (2020). Assessment of terrace gardens as modifiers of building microclimate. Energy and Built Environment, 3(1): 1-15.

Chow, W. T. L. & Brazel, A. J. (2012). Assessing xeriscaping as a sustainable heat island mitigation approach for a desert city. Building and Environment, 47: 170-181.

Ebru, E. S. (2013). Pedestrian Zones. Advances in Landscape Architecture. InTech. DOI: 10.5772/55748.

Harmanescu M. (2014). Living the space from tara hategului: Building Places and Landscapes as Collective Identity and Memory. Planning and Designing Sustainable and Resilient Landscapes. Springer Geography. Springer. Dordrecht. pp: 17-31.

Hofman, M. P. G., Hayward, M. W., Kelly, M. J. & Balkenhol, N. (2018). Enhancing conservation network design with graph-theory and a measure of protected area effectiveness: refining wildlife corridors in Belize, Central America. Landscape and Urban Planning, 178:51-59.

Huang, D., Huang, J. and Liu, T. (2019). Delimiting urban growth boundaries using the CLUE-S model with village administrative boundaries. Land Use Policy, 82:422-435.

Ismaeil, E. M. H. & Sobaih, A. E. (2022). Assessing xeriscaping as a retrofit sustainable water consumption approach for a desert university campus. Water, 14(11): 1-30.

Kazemi, P. F., Beecham, S. and Gibbs, J. (2011). Streetscape biodiversity and the role of bioretention swales in an Australian urban environment. Landscape and Urban Planning, 101 (2): 139-148.

Lau, J. T. and Mah, D. Y. S. (2018). Green wall for retention of stormwater. Pertanika Journal of Science and Technology, 26 (1): 283-298.

Leroy, C., Florence, P. K., Legras, M., Lederf, F., Vincent, M., Polaert & I, Marcotte. (2016). Performance of vegetated swales for improving road runoff quality in a moderate traffic urban area. Science of The Total Environment, 567 (1): 113-121.

Lier., V. H. N. (1998). Sustainable land use planning: an editorial commentary. Landscape and Urban Planning, pp: 79-92.

Liu, D., Yang, X,, Gao, J., Ran, Q., Zhu, G., Yuan, L., Zheng, D., Guo, L., Zhao, L. & Tang, Q. (2022). Smart solar-panel umbrella toward high-efficient hybrid solar and rain harvesting. Energy Technology, 11(22): 1-8.

Loper, S., Shober, A. L., Wiese, C., Denny, G. C., Stanle, C. D. & Gilman, E. F. (2010). Organic soil amendment and plant performance in simulated residential landscapes, HortiScience, 45(10): 1522-1528.

Matthews, T., Lo, A. Y., Byrne, J. A. (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landscaping and Urban Planning, 138:155-163.

Nivya and Keerthishankar (2022). Hydrogels: boon to arid floriculture. In: Recent Innovative Approaches in Agricultural Science, 1- 119-124.

Paoletti, P. G. (1999) Using bioindicators based on biodiversity to assess landscape sustainability. Agriculture, Ecosystems and Environment, 74 (1): 1-18.

Peng, J., Liu, Y., Corstanje, R. & Meersmans, J. (2021). Promoting sustainable landscape pattern for landscape sustainability. Landscape Ecology, 36(3): 1839-1844.

Peng, J., Zhao, S., Dong, J., Liu, Y., Meersmans. J., Li, H. & Wu, J. (2019). Applying ant colony algorithm to identify ecological security patterns in megacities. Environmental & Modelling Software, 117: 214-222.

Rodie, N. S. & Streich, A. M. (2009). Landscape sustainability. Neb Guide, University of Nebraska-Lincoln extension, Institute of Agricultural and Natural resources, pp:1-4.

Salici, A. (2013). Greenways as a Sustainable Urban Planning Strategy. Advances in Landscape Architecture, pp: 645-660.

Sharath, M. K. & Peter, K. V. (2019). An environment friendly landscaping. In Sustainable Green Technologies for Environmental Management, Springer: Singapore, pp. 1-27.

Sharma, R. & Malaviya, P. (2021). Management of stormwater pollution using green infrastructure: The role of rain gardens. Wires Water, 8(2): 1-21.

Smith, D. B. & Zeder A M (2013) The onset of the Anthropocene. Anthropocene 4: 8-13.

Susorova, I. (2015) Green facades and living walls: vertical vegetation as a construction material to reduce building cooling loads: In: Eco-efficient materials for mitigating building cooling needs. Design, properties and applications. Pp. 127-153.

Timur, B. Z. & Karaca, E. (2013). Vertical Gardens. Advances in Landscape Architecture, 1(1):1-68.

Wu, J. (2013.) Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landscape Ecology, 28: 999-1023.