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Desertification in Western Rajasthan (India): Causes, Effects and Mitigation Measures

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Authors' contributions

This work was carried out in collaboration among all authors. Author TUY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SKA, AU and AT managed the analyses of the study. Author YGH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Desertification is a type of land degradation in drylands whereby biological productivity is reduced due to natural or anthropogenic factors converting them more arid. Thus, it is emerging global environmental issues and problems, India inclusive. It is a threat for both human beings and ecological systems. The various causes of desertification are attributed to climatic change which is the combination of both natural and anthropogenic factors. These causes leads to destruction of vegetation that result in extinction of species, soil erosion and soil infertility, increase vulnerability of natural disasters, pollution of soil, air and water, rise of famine, poverty, forcing mass migration and social conflicts. Rajasthan state of India due to its proximity to Thar desert in western part of Rajasthan also gets impacted to great extent by the effects of desertification and industrialization to as Rajasthan has a rich source of limestone and gypsum. The actions of desertification in western Rajasthan leads to destruction of ecological system and loss of biodiversity. The mitigation of desertification effects is critical and essential in meeting the millennium development goals. Such that the human well-being of dry land people, which constitute of about 90% of whom are in developing countries of the world, including India, lagging significantly behind. The combination of

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high variability in ecosystem conditions in dry lands and high level of poverty leads to situation where societies are vulnerable to a further decline in human well-being and existence. Hence mitigating desertification, thus facilitates eradication of extreme poverty, integrated land and water management, protection of Vegetation cover as envisioned in the millennium development goals (MDGs). Hence, individuals, communities, national and international, NGOs have to act actively to mitigate these effects and causes of desertification as a whole.

Keywords: Causes; effects; desertification; mitigations.

1. INTRODUCTION

According to UNESCO [1], "one third of world's land surface is threatened by desertification". Across the world the land degradation in arid, semi-arid and sub-humid areas is due to various factors including climatic variations and human activities. Desertification has become a significant environmental problem on global scale and represents a critical threat to biodiversity, socioeconomic development, and sustainability. It affects livelihood of millions of people who depend on the benefits of ecosystems that dry lands provide Kundu, et al. [2]. According to United Nation Convention to Combat Desertification UNCCD Paris, [3], desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. It has a complex web of impact on ecological processes including negative changes in vegetation properties (e.g. vegetation cover, biomass, and density), loss of biodiversity and soil fertility, landscape patterns and microclimatic changes over dry regions at different geographical scale (2). Drylands are one of the largest terrestrial biomes of the planet (4) and cover approximately 40% of the land surface UNCCD [3].

Drylands are difficult to define but are usually defined and measured based on the ratio of annual precipitation (P) to annual potential evapotranspiration (PET). A P/PET ratio of 0.2–0.65 is indicative in dryland. This relationship is also known as the aridity index (AI) and expresses the aridity or temporary scarcity of water supply relative to atmospheric demand for moisture in a region, Huang et al. [4]. Rajasthan accounts most of the desert land (23 Mha), followed by Gujarat, Maharashtra and Jammu and Kashmir (13 Mha each) and Orissa and Andhra Pradesh (5 Mha each), Kundu et al. [2]. About 85% of the Thar Desert is located in India and the rest part lies in Pakistan. Indian part of Thar Desert is extended towards the Punjab and Haryana states in the north and towards the Gujarat state in the south, Mann HS, Malhotra SP, et al. 1997. Among different states of India, Rajasthan solely contains 91% of the desert (2.08 million sq. km.), which is about 61% of the geographical area of the state, Sinha et al. [5]. The western districts of the state fall under the Great Indian Desert; however, the surrounding districts like Bikaner, Churu and Nagaur are also under risk due to desertification related issues, Kundu et al. [2]. Increasing pressure of population and grazing over this fragile ecosystem has been a serious issue and major threat to desertification.

2. DESCRIPTION OF THE STUDY AREA

The big Indian desert 'Thar' is located in western part of Rajasthan state. The study area is encompassed by three districts, i.e. Bikaner, Churu and Nagaur (Fig. 1). These districts are situated in north-western part of Rajasthan. Geographically, the area lies between longitude 73° 22'E to 75° 01' East and latitude 27°00' to 28° 19' North. It has a total area of 27,244 sq. km and comprises 7.96% area of the state daily temperature of the area ranges between 40 and 45°C during summer. However, sometimes the summer temperature reaches up to 49°C. The minimum daily temperature of the region stays on around 20–29°C. The average annual rainfall ranges from 20 to 40 cm in the region. Rajasthan state is climatically divided into ten agro-climatic zones, and the study area comprising three districts (Bikaner, Churu and Nagaur) belong to the hyper-arid irrigated western plain and transitional plain of inland zone (Fig. 1). This region is characterized by sandy soil and with bare rock outcrop. Sparse vegetation comprising of mainly thorny and succulent grass species such as *Acacia Senegal,* Babul, Khejri is quite common in this region.

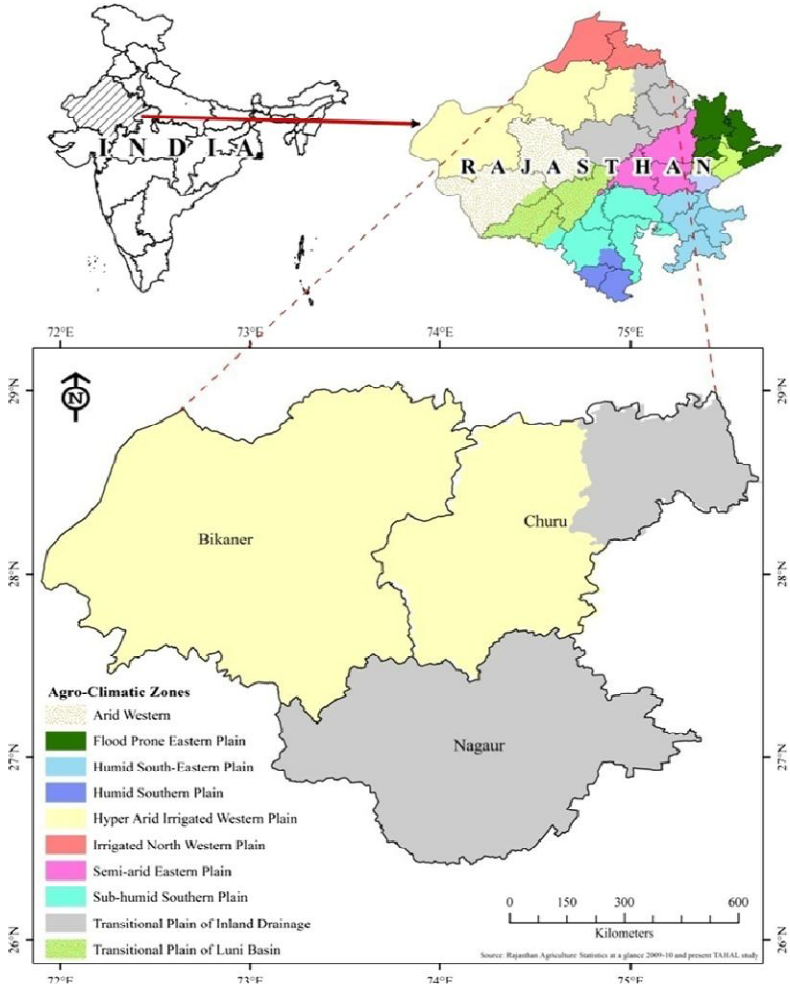

Fig. 1. Map of Western Rajasthan depicting climatic zones of the region
Source: Kundu A., Dutta D., Patel N. R., Saha S. K., 2017 [2]

3. OBJECTIVES OF THE STUDY

The general objective of the study is to accessed the causes, effects and mitigation measures of desertification in western Rajasthan India.

The specific objectives of the study are as follows:

1. To accessed the causes of desertification in western Rajasthan region.
2. To find out the effects of desertification in western Rajasthan region.
3. To identify mitigation measures of desertification in western Rajasthan India.

4. METHODOLOGY

The research strategy is survey method based on a combination of quantitative and qualitative data acquired through analysis of relevant Information generated through remote sensing and field studies by the Central Arid Zone Research Institute (CAZRI), Jodhpur, during the last three decades, especially on the natural resources and their degradation [5]. Shankarnarayan and Kar et al. [6] provided the data base for an understanding of the desertification problem and its impact on the fragile ecosystems in western Rajasthan region.

5. CAUSES OF DESERTIFICATION

The level of interaction of different causal factors on a temporal scale is another point of discussion, Lambin E, Chasek P, Downing T, et al. [7]. Generally, the causes of desertification can be attributed to the interaction of direct and indirect factors that may vary or interact spatially

or temporally, including climate conditions, soil properties, vegetation cover, and socioeconomic conditions, Hellden et al. [8]. Several studies have focused on analyzing the influence of either climate factors or human activities. However, without a simultaneous intensive analysis of both factors (direct and indirect), the results may be easily misinterpreted or bias, leading to the design and adoption of inefficient strategies in the fight against desertification, Feng Q, Ma H, Jiang X [9]. Among the direct factors that contribute to desertification are, management and land use, irrational and use of water resources, deforestation, overgrazing, and climate related processes. Some of the indirect factors are population growth and density, urbanization, politics, governance, economic conditions, technology, and globalization, Sterk et al. [10].

5.1 Climatic Variability

Has been considered as a leading cause for degradation of natural resources in an environment. A final aspect that cannot be ignored is climate change. The latest and most recent report called Assessment Report. (AR no. 5) from the Intergovernmental Panel on Climate Change (IPCC), states that, in the present century, the global temperature could increase by 4.5 C, causing greater evapotranspiration and more water to be retained in the atmosphere, Simmons and Mathew [11]. Drylands frequently experience climate extremes and drought, and climate changes are only expected to increase the frequency of or exacerbate such desertification caused by climatic or anthropogenic induced processes. It negatively affects the productivity and sustainability of land within an ecosystem. It is notable that exhaustion or depletion of vegetation cover actively plays a key role in land degradation, however reduction in plants and perennial cover is considered as an indicator of the onset of desertification in environment. Lands converted to desert like condition due to a number of reasons, but the major cause or triggers of the desertification that is occurring around the globe today is caused by anthropogenic activities on lands, which are extremely vulnerable to over exploitation of natural resources and improper agricultural methods and practices. Hence, due to the proximity of Thar Desert to Rajasthan, the effects of desertification is averse to host communities, because of the reduction in the capacity of the land to support particular land use activities, Blackier and Brookfield [12].

5.2 Overgrazing and Desertification

Have been always closely associated together in arid regions, grass and other small vegetation is necessary to maintain the soil in place to prevent erosion and further damage to the soil, there by maintaining it fertility. Hence it is the contradiction of life that especially in these vulnerable and less developed regions, animal herding is often the only livelihood people can have and there are no restrictions in areas or places that would regulate the maximum number of animals per space. When dwellers gather and keep large number of many animals in one area or space, grasses start dying due to that their roots are often weakened by animals constantly stepping on them and plucking out newly re-growing parts before plants have time to replenished itself resistant enough and to multiply in the area.

5.3 Unsustainable Agricultural Practice

The world's dry lands cover approximately 40 percent of the total land mass. They are habitat to more than 2 billion people across the globe, hence many of these areas are farmed or cultivated, despites their fragility and can easily turn barren due to aridity conditions, Kundu A et al. [2]. Inconsiderate farming techniques and practices likes such as heavy tilling, excessive use of chemical fertilizers, planting of unsuitable crops and leaving soils exposed to wind and rain erosion, farmers only speed up the process of desertification in exchange for poor quality crops with low and unsustainable economic value. Subsequently while preparing the soil for sowing, natural vegetation that holds the brittle soil in place is removed and destroyed letting the last bits of the productive soil layer fully erodes or wear away in just a few short seasons at an area.

5.4 Deforestation

This is among the leading anthropogenic causes of desertification. Forests are being cut down at an accelerated phase much larger scale than ever before, to be used as fuel to provide varieties of products we use in our daily life, or rather to create more space for agricultural practices to meet the growing human population needs. When the forest is destroyed or cut down for use there exist no roots that would hold soils in place, there is no canopy that would shield the ground from the direct rainfall or from the sun's heat in the area. Hence, the bare soil then easier dries out and turns to dust, which

can be eroded, blown and washed away in a single storm, which resulted to arid conditions, Kundu A et al. [2].

5.5 Climate Change

This plays active role on the health of our lands, as climate change can lead to land degradation due to many reasons. Climate change tends to accelerates the progress of desertification in many places, UNCCD, [3]. As such, developmental activities of humans through the removal of natural vegetation from landscapes, we alter or modifies radically the water absorption capacity of soils. With less permanent vegetation that would help retain moisture contents in soils and with less moisture evaporating into the air from plants, leads to less clouds form in that particular area, thus also less rainfall throughout the year and leads to also rainfall variability in the area.

With significantly reduced rainfall, drought occurs and exacerbates negative conditions such as failing harvests, drying creeks and drying or reduction in underground water, poor pasture that weakens livestock, and more frequent leads accelerated outbreaks of wildfires that destroy remaining vegetation cover, Kundu A et al. [2]. Hence, due to these problems of arid condition, it pressure people to slip into the vicious cycle of repeating all the previously listed causes of desertification actions, which naturally open up the door to the ecological catastrophe of irreversible land degradation of severe magnitudes.

5.6 Population Pressure

Due to alarming growth of human and livestock population in arid and semi -arid regions, resulted to urbanization and industrialization, which aggravated the man-land ratio situation by way of clearing the forest for fuelwood, and construction of housing, Kaushalya, [13]. This has resulted in phenomenal increase in population density of this region from 102 individuals per sq.km in 1961, Census of India, [14]. 207 individuals per sq.km in 1981.According to UNDDD, 2010-2020 [15], drylands or arid regions takes up to 41.3% of the global land surface, up to 44% of all the world cultivated system are in the dryland, plant species endemic to the dryland makes up to 30% of the plant under cultivation. These population exoduses aggravated desertification in western Rajasthan.

6. EFFECTS OF DESERTIFICATION

Desertification has multi-dimensional and accelerated effect to humans and ecological system as explained in document called 'Desertification the invisible frontline, UNCCD, [16]. The document outlined that: *"desertification is a silent, invisible crisis that is destroying communities on a global scale or dimension,* Kundu, a et al. [2]" opined that through the process of desertification economically productive land becomes less productive and, if not stopped or controlled, it develops as an arid - like conditions incapable of sustaining the communities or habitats that once depended on it for sustenance. There exist serious and complex web of problems that have arisen from worsening land degradation of the Earth's dry lands, which are home to 2,000 million people, comprise of 44 percent of the world's cultivated land and sustain 50 percent of the world's livestock, Kundu, a et al. [2].

6.1 Destruction of Vegetation

Desertification reduces the ability of land to support plant life. Loose and exposed soil tends to buries plants or exposes their roots to the Sun, so they cannot fulfill their function effectively. With plants dying, already scarce rainwater gets washed away instead of being drawn into the soil contents, which only scales up the problem as remaining plant lacks enough moisture contents to withstand the dry spells as they used to in search for the nutrient for growth. However, also if the land is used for grazing at this stage, it leads to faster loss of plant species and total degradation emanates. Due to degradation of the sandy landforms, in the study area. The basal cover of these plant species declines from 5.14 to 2.4 per cent. The total vegetation cover declines from 6.59 to 0.95 percent and its yield declines from 2 to 4 t ha-1to less than 1 t ha-1, Shankar and Kumar [17].

6.2 Soils Become Infertile

Top soil is crucial for plant growth because it contains most of the organic matter contents and 50 percent of important nutrients such as phosphorus and potassium. It is in top soil, where large pores and soil aggregates form, allowing for proper water infiltration and aeration and retention. When desertification occurs, the top most productive layer of the soil gets blown or washed away from the surface rather quickly because there is no vegetation that would protect and sustained it hence both the nutrients and

organic materials are lost. As the soil dries out, it hardens, and it becomes difficult for any rainfall that does occur to penetrate below the soil's surface due to the arid condition of the soil. Hence as an outcome of these unfavorable conditions, plants grown on these damaged soils strive and often fail to produce sufficient yield outputs. Thus, the remaining soils became infertile, instead of growth medium to the plants. People living near affected areas can be affected by desertification, which can cause flooding, poor water quality, dust storms, and pollution, Morgan [18].

Thus, due to poor soil mantle in the study area, the rocky/gravelly pediments support very poor cover of Dactyloc-tenium sindicllm -Eleusine compressa types of grasses in the study area. Upon degradation, it is replaced by Aristides fillli-cllata-Oropetium thomaeumtype of cover in the land soils in western Rajasthan, of which is the result of desertification, and affect the soil fertility in the study area.

6.3 Soil Erosion

Desertification effects are related to one another, hence link between soil erosion and other consequences of desertification only entails this, as erosion is another negative consequence but also a catalyst of previously mentioned issues and problems related to desertification in the study area. The factors that influence soil erosion includes rainfall (quantity and variability), winds (direction, frequency and speed), land use pattern and management, topography, soils properties, Morgan [18]. In many cases, increased water runoff from degraded areas wreaks havoc on neighboring lands, eroding soils, damaging vegetation and making soils extremely vulnerable to encroaching desert. Furthermore, at these stage the infertile weakened soils are exposed to wind vulnerability, which often picks up last pieces of drying top soil at the stage and mixes them with dust from already degraded parts of the soil, hence, exacerbates the problem and creating extensive dust storms in the study area.

Approximately 92% of the area in Rajasthan is currently affected by desertification, with about 76% from wind erosion, 13% by water erosion, and another 4% area is affected by water logging and salinity/alkalinity [6]. Water erosion and salinity seriously affect agriculture, aggravating poverty and threatening the food and water security in this study area. Understanding the causes of land degradation in Rajasthan is crucial to help the Indian government draft policy to protect and improve the livelihoods of the communities living there to provide mitigation measures of desertification in the study area.

6.4 Increase Vulnerability of Natural Disasters

Desertification makes natural disasters worse because it reduces natural resilience of ecosystems. Which means that affected areas and even adjacent areas are vulnerable to its effects hence have compromised capacity of withstanding extreme arid conditions in the area. Events such as soil erosion, flash floods, landslides and dust storms, becomes aggravated in areas with heavily degraded infertile soils. Without vegetation stabilizing the soil and slowing down the runoff flow, rainwater flows faster and leads to flooding's of human settlements in the blink of an eye, instantly. Except causing damage, flood water also picks up many unwanted pollutants while making its progress through urban areas, landfills, or agricultural lands where fertilizers and pesticides were used and washed away to water bodies. It results to eutrophication, which affects the aquatic ecosystem, by decreasing the dissolved oxygen (DO) and leading to high biological oxygen demand (BOD) hence kills the aquatic animals or organisms. Also sand storms are another big issue, mainly because wind-blown particles (including those that are polluted) can travel long distances and cause health problems to people even in distant urban areas.

Desertification leads to a loss of agricultural productivity, thereby threatening the food security and sustainable development of the region and the country. It is especially concerning given India's massive population and increasing rates of growth in both numbers of people and standard of living, hence people are vulnerable to natural disasters, such as drought, erosion, flooding etc. Desertification has also aggravated rural poverty and influenced resident health. For example, Singh et al. [19] studied the nutritional status of children aged 0–5 years in western Rajasthan and observed that among a total of 914 children, stunting (Chronic malnutrition measured as by the stunted growth of children) was observed in 53% of children. Additionally, 60% were underweight, and 28% were wasting, indicating extremely acute malnutrition.

6.5 Ground Water Pollution

Vegetation plays an important role in cleaning our water. Plants and trees function like natural water filters, storing pollutants, such as heavy metals, pesticide residues, fertilizers and other, in their own bodies. Hence as mentioned previously, grasses and other perennial plants plays significant role in prevent water runoff by slowing it down and promoting rainwater infiltration into soils thereby improving water retention capabilities of the soil. Barren soils lack this green filter, and therefore, many harmful substances enter groundwater reservoirs or easily wash off into lakes and rivers. Besides constantly eroding soils by creating gullies and channels each time it rains, water also picks up loosen soil particles and transports them into water bodies. This leads to increased sedimentation and both processes disturb aquatic ecosystems and deteriorate water quality. What's worse is that these effects can be felt even thousands of miles away from where the problem originated. There exist tremendous records of water scarcity and pollution problems that are linked to desertification or other forms of land degradation across dry African and Asian countries. Western Rajasthan ground water is polluted due to its proximity to Thar Desert and industrial area, as a result of raw materials availability such as gypsum and limestone. Environmental pollution has created a snag through industrial disposals in the area, the increase in the toxicity level by heavy metals deposition has become a threat to all the living forms in the ecosystem in the study area.

6.6 Rise of Famine, Poverty and Social Conflicts

Desertification is a serious form of land degradation that results in the destruction of natural ecosystems and the end of services they provide for us. This includes natural filtration of water for drinking, climate regulation, recycling of nutrients, carbon sequestration, soil regeneration. When ecosystems cease to support us and our livestock, only negative effects happen. The Negative impacts includes, prolonged episodes of famine, diseases outbreaks from water scarcity, conflicts for thinning resources and over exploitation of the scarce natural resources and death of people, children, animals. Many countries across the world especially Sahel area of Africa are experiencing insecurity that only gets worse every year. Climate change, bad management of scarce resources, weak political structure only lead to hunger, which in turn gives rise to conflicts in the study area and globally.

6.7 Forcing Mass Migrations

Human have on constantly on the lookout for fertile lands to cultivation of food and established their habitat and prosper over long time periods. However, since time immemorial across civilization, desertification events have been a major driver behind migrations of large human populations.

6.8 Historical Collapses of Civilizations

There are many historical accounts of how various civilization across human history experienced collapse of their civilization as drought and desertification occurred and change their lands into arid condition. This is due to that, people lost their capacity to grow food, water resources became scarce and their animals got weak from not having enough to eat for their survival. Hence, these negative impact are connected to social well-being's of the people in the study area. As soon as livelihoods are endangered, people turn against each other, which set in motion series of events that lead to the collapse of their civilizations in the regions such as in Bikaner and Churu districts in the study area of western Rajasthan.

6.9 Extinction of Species

Extended droughts, prolonged flooding or sudden extreme changes or variability in temperature can extensively deplete food sources of biodiversity leading starvation in an ecosystem. Biodiversity that once survived in a fertile and productive climate may not survive in a newly arid region. With a variability or changing ecosystem, biodiversity must adapt to their new climate or migrate to a more favorable climatic environment. If the biodiversity fails to adopts to the withstanding changes in the environment they tend to be at extinct. This is another very alarming aspect of the desertification problem, because we need biodiversity ecosystems to survive. As many as 700 species of plants are found in the Thar Desert, of which about 100 species are of grass varieties alone. Most of the plant species found here are deep-rooted and tenacious enough to withstand extended droughts and efficient enough to gain biomass rapidly during a favorable season in the study area. Thar Desert vegetation must be extremely hearty to endure such conditions, it is mostly herbaceous or of stunted scrub on the hills, while small bushes like acacia and euphorbia species

may also be found. The Khejari tree (prosopis cineraria) grows widely throughout the plains and other trees occasionally dot the horizon as well. About 23 species of lizard and 25 species of snakes are found here and several of them are endemic to this region. Some wildlife species, that are fast vanishing in other parts of India are found in this desert in large numbers, such as the great Indian bustard, the black buck, the Indian gazelle and the wild ass in the Rann of Kutch region, thus as a result of effect of desertification in western Rajasthan majority of the species are at extinctions. There is need for abundance of plants and animal species for nutrients and mineral cycles in the environment for ecological sustainability. If biodiversity ecosystems disappear, we will be left with pollution, drought, hunger and lack of resources.

Although, the expansion of desertification in drylands is happening around the world, as well as numerous studies and years of research is also available, but no accurate estimates of the global reach of desertification is in existence yet, Reynolds et al. [20]. Millennium Ecosystem Assessment estimates that 10–20% of drylands are degraded and that up to 6% of the population of dryland regions lives in arid areas, MEA [21]. Regionally, Africa and Asia present the highest degradation, Olderman [22] and contain more than 50% of drylands worldwide. Due to interplay of diverse factors in these regions has generated adverse consequences. In the drylands of Asia, desertification is related with urbanization and commercialization processes and developments, as against other regions across the globe.

In Table 1 the major causal factors and consequences of desertification in western Rajasthan India, hence some of these factors are globally manifested and interconnected to the region, such as climate change.

Table 1. Causal factors and consequences of desertification

Causal factor	Consequences
Land use changes	Reduced soil structure and Permeability, Depletion of nutrients and organic matter in the soil Increased susceptibility to erosion and soil compaction, Loss of vegetation cover and biodiversity Increased dune mobilization and frequency of sand storms
Deforestation and overgrazing	Loss of biodiversity and/or biomass, Degradation of vegetation cover, Establishment of secondary vegetation, Intensive/extensive production systems surpassing the carrying capacity, Increased susceptibility of soil to erosion, compaction, run-off, and Aeolian desertification, Increased rate of evapotranspiration and, consequently, aridity
Crop irrigation and over-exploitation of water	Greater threat of salinization, Increased water erosion, Decreased crop yields, Depletion of groundwater, Reduction in the quantity and quality of scarce water resources, leading to migration (one of the more visible socioeconomic consequences of desertification)
Lack or failure of planning policies	Overpopulation, Resource exhaustion, Poverty, Overexploitation of marginal lands
Forest fires	Increased erosion, Migration of rural peoples to urban areas,
Inter-annual variability in rainfall and drought	Reduced vegetation productivity, Increased bare soil cover, Greater tendency of erosion, Increased vulnerability of rain-fed agriculture crops and other systems dependent on temporary rainfall Migration
Urbanization	Land use changes, Biodiversity loss, Flooding, Greater climate variability, Overpopulation and increased poverty
Aridity	Reduction in annual precipitation, Increased rate of evapotranspiration, Reduction in soil humidity, Increased incidence of fires Economic losses for rain-fed farmers and migration,
Technological developments	Expansion of infrastructure for irrigation, Increased use of fertilizers and pesticides, Decreased livestock mobility in intensive livestock production systems

Source: (Geist and Lambin 2004, Desertification: Causes and Countermeasures) [8]

7. CONCLUSIONS

The deterioration of productive ecosystems is an obvious and serious threat to human progress and hence the progress of desertification must be controlled. In combating desertification and drought in the study area and globally the participation of local communities, rural organizations, national and state governments, non-governmental organizations and international and regional organizations is essential. Resource depletion, reduced carrying capacity, and climate change, which are associated with desertification, will undoubtedly undermine the quality of life, economic development, and ecological stability in the study area and global biodiversity of affected regions around the globe. Climate change and other anthropogenic activities are the major factor in accelerating the desertification process in the study area. Hence poverty eradication programs must be initiated for the sustainable management of land resources as well as the inhabitants, who deserve some alternative (non-land based) livelihood system. The increase of human and livestock population in Thar Desert in the study area has led to further deterioration in the desert ecosystem and hence the human and animal populations must be regulated. The campaign against desertification should be a priority among the efforts to achieve optimum and sustained productivity.

The fight against desertification is a complex, multi-dimensional and often diffuse objective, given that it requires political will and compromise among diverse actors or stakeholders. The participation of local and/or interested actors and social resilience are crucial in the mitigation process of desertification. The fight against desertification should involve integral measures and socioeconomic development programs based on the implementation of local actions, regional and under a global perspective, to achieve the desired goals. Desertification should involve integral measures and socioeconomic development programs based on the implementation of local actions, regional and under a global perspective, to achieve the desired goals.

8. MITIGATION MEASURES OF DESERTIFICATION

Since 1994, July 17 has been designated as "World Day to Combat Desertification and Drought", Armon [23], with the objectives of (1) making and highlighting the complex problem of desertification more visible; (2) creating awareness of the role or function of land in the production of food, employment, and local stability; and (3) promoting international efforts for combating desertification from global point of view. Two decades after the Earth Summit in 1992, the United Nations Conference on Sustainable Development (Rio + 20) recognized the necessity of taking urgent actions to reverse land degradation, UNEP, [24]. In 2015, the General Assembly of the United Nations approved the "2030 Agenda for Sustainable Development," integrating 17 Sustainable Development Objectives (SDO) and 169 goals urges countries to protect, reestablish and promote the sustainable use of terrestrial ecosystems, Armon [23]. In particular, goal 15.3 proposes fighting against desertification, rehabilitating degraded lands, and achieving Land Degradation Neutrality (LDN) by 2030, Orr et al [25]. LDN refers to a condition, whereby the amount and quality of land resources necessary that are to support ecosystem functions and productivity and enhance food security and sustainability. The LDN concept is based on three phases, Armon [23]: (a) It is ambitious and developmental but not impossible to entirely avoid further land degradation (zero land degradation) in an environment.; (b) Approximately 10–20% of global lands are already degraded due to the development; and (c) Existing experiences confirm that land productivity and the provision of ecosystem services can be recovered. Chasek P, Safriel et al. [26]: describes the neutrality mechanism considers the direction of change as well as the magnitude of change, based on expected gains and losses in the measures of land natural capital. Orr B, Cowie A, Castillo Sanchez V et al .2015. [25].

Several international and national successful methods have been implemented in the reclamation of degraded lands and the fight against desertification. More than 190 countries have acted actively to control the desertification. Armon [23]; however, despite that, there exist debate about the best solution to mitigate desertification. But an integrative, sustainable, holistic, multidimensional, long-term rehabilitation system could be the best way towards achieving the desired goal. Some methods may include water use quotas, sustainable grazing practices, land use and water management, returning marginal cropland into forest, wind-shelter forest,

sustainable cultivation practices, and stabilize ecological zones between oases and deserts, Zhang and Huisingh D. [9].

8.1 Integrated Land and Water Management

Are key methods of desertification prevention. However, measures that protect soils from erosion, salinization, and other forms of soil degradation that acerbates arid condition effectively prevent desertification. Sustainable land use pattern can address human activities such as overgrazing, overexploitation of plants, trampling of soils, and unsustainable agricultural practices that exacerbate dry land vulnerability toward aridity. Management strategies include measures to spread the pressures of human activities, such as trans-human (rotational use) of rangelands and well sites, stocking rates matched to the carrying capacity of ecosystems, and diverse species composition. Enhanced and Improved water management system in turn can enhance water-related services. These practices may include use of conventional water-harvesting techniques or methods, water storage, and diverse soil and water conservation techniques, which will significantly mitigate the menace of land degradation.

8.2 Land conservation of Vegetative Cover

These can serve as a major instrument for prevention of desertification. Enhanced Maintenance of vegetative cover to protect soil from wind and water erosion is a key preventive measure against desertification. In an environment, due to the roles played by vegetation toward modification of micro climatic condition as well as carbon sequestration, its conservation is mandatory to prevent desertification.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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