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Soil Erosion and Desertification: What are their Implications on Agricultural Land of Rajasthan?

Pakin Pongpaiboon

Independent Researcher,Jaipur, Rajasthan, India

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ABSTRACT

Desertification is a major problem in the drylands of India, affecting 173.64 million hectares, or 53% of the total area and about 177 million people. The problem is escalated in the northwestern part of the country which includes Rajasthan. Approximately 6 % of the hot arid areas of the country is located in Rajasthan and about 92% of the area in Rajasthan is currently affected by desertification and another 4 %area is affected by waterlogging and salinity/alkalinity. As the productivity of land is reduced by these erosive processes, food production and agricultural sectors are also affected. The loss of productivity of this scarce resource would not only affect humans but also livestock populations that are dependent on the grass-based food source.Understanding the causes of soil erosion and desertification as well as their impact on agricultural land is essential such that further policies can be implemented to mitigate the situation. This knowledge would also aid in meeting the Millennium development goals set by the UN. This is a review paper which seeks to understand factors that contribute to soil erosion and desertification within the geographical area of Rajasthan and how they impact agricultural land based on previous research on land usage, soil ecology and properties in Rajasthan and other regions of the world. The research has identified overgrazing, loss of Soil Organic Carbon (SOC) and other losses of essential soil nutrients by erosive processes as major contributor to diminishing productivity of land.

KEYWORDS: Soil erosion, Desertification, Agricultural land of Rajasthan

INTRODUCTION

Desertification is a complicated global threat with negative socio economic influence [1]-[2]. As per the assessment of the Food and Agriculture Organization(FAO), about 19.5% of dry lands globally is affected by soil degradation[3].Reference [4] claimed that 6-7 million hectares of land is lost every year due to land degradation processes including soil erosion and desertification. The United Nation Environment Program (UNEP) defined desertification as "land degradation in arid, semi-arid, and dry sub-humid areas resulting mainly from the adverse human impact" [5]. However, the most widely accepted definition of desertification is provided by the United Nations to Combat Desertification (UNCCD). According to the UNCCD, desertification is "land degradation in arid, semi-arid and sub-humid areas resulting from various factors including climatic variations and human activities" [6]. The United Nation Environment Program (UNEP) defined desertification as "land degradation in arid, semi-arid, and dry sub-humid areas resulting mainly from the adverse human impact" [5]. Desertification and land degradation are outcomes of anthropological activities that have led to a multitude of environmental problems[7]. Some factors that cause desertification include drought, soil erosion ,vegetation degradation by heavy livestock grazing, mining activities, growing populations, poverty, poor infrastructure and lack of access to market,wrong policy development and agricultural and environmental research systems[8]-[9]. Other anthropogenic factors that contribute to desertification process include high population growth and density and soil slope and soil texture [10]. Drought, land usage, scarcity of water, deforestation and over irrigation are also contributing factors. A recent global estimate by [11] suggests that 9% of the total area is under very high desertification risk and is predicted to be increased to 23% by the end of this century.

In India, according to [12] about 82.64 Mha of semi-arid, arid, and dry sub-humid areas were affected by various desertification processes. Some major contributors to desertification in India includes erosion of water (26.21 Mha), degradation of vegetation (17.63 Mha), erosion by wind (17.77 Mha), and frost shattering (9.47 Mha) [13].India, a country where the average annual rainfall is less than 75% ,the increase in temperature and increase in rainfall will cause a meteorological drought[14].An increase in temperature with decreased rainfall is also is also a contributor to aridity which is a major driver of desertification [15].

The state of Rajasthan is divided by the Aravali range of hills into two distinct regions- West of Aravali and East of Aravali. Additionally, the proximity of the state to the Thar Desert also contributes to the problem of desertification. As a percentage of the geographical area of the state, 61% is covered by desert. Moreover, Rajasthan accounts for 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)[16]. About 62.90% of the total area of Rajasthan is under the desertification process [17].The Jhunjhunu and Sikar districts of Rajasthan which covers 13.11% and 12.94% of the total area of the state respectively are highly sensitive to desertification [18].

Given that approximately 62.90% of the total area of Rajasthan is under the desertification process[17], and in the future, economically vulnerable tropical countries, including Peru, Brazil, a number of states in Western Africa, Cameroon, Ethiopia, Somalia, Kenya, Yemen, Southern Pakistan, India, Myanmar, Southeast China, Philippines and Indonesia are projected to be hit particularly hard by increased soil erosion[19], a collective effort by individuals, communities and the state must cooperate to alleviate the situation in order to maintain sustainable agriculture in the future.

The findings of this study will help contextualize the various drivers of soil erosion and desertification as well as the biochemical factors involved in soil quality and agricultural production. Various studies have well documented and mapped the erosive processes that lead to desertification in Rajasthan; however, these researches have been carried out by focusing on identifying risk factors, geographical mapping and indicators. The present study examines soil erosion and desertification in Rajasthan by building on previous data and analysis and focusing on the perspective of soil ecology, namely how erosive processes influence the productivity of agricultural land.

DESERTIFICATION STATUS MAPPING OF RAJASTHAN

Reference [20] established a desertification/ land degradation status map (DSM) of India on a scale of 1:500,000 using remote sensing satellite(IRS)-Resourcesat AWiFS data in collaboration with ancillary data and base maps. The results for the state of Rajasthan, which will be used as a baseline to assess the implications of soil erosion and desertification on agricultural land in Rajasthan, can be found in Table 1.

According to the results of the study, the total land area undergoing the process of degradation is 105.48 mha, which is 32.07% of the total geographic area (TGA) of the country. Additionally, Rajasthan has the largest area (21.77% of the total geographical area) under land degradation [20].

Table I. Rajasthan distribution of land degradation area (ha)

Water erosion	3,840,503
Vegetal degradation	2,138,495
Eolian	15,203,070
Frost shattering	-
Salinity/Alkalinity	364,643
Mass movement	-
Waterlogging	4,108
Rocky/barren	1,383,473
Others	31,875
Total(ha)	22,966,267
Area% of TGA of India	21.77

CAUSES AND CONSEQUENCES OF DESERTIFICATION AND SOIL EROSION IN RAJASTHAN

By the arid zone standard, Rajasthan is one of the most densely populated desert areas in the world. The density population per square km is 48 as compared to 3 persons per square km in most desert regions of the world. With a base of roughly 3.567 million in 1901, the population of these arid areas has registered a linear increase to 10.236 million (roughly about threefold increase) over the base year of 1901 to 1977. To satisfy the land requirements of the growing population in these arid areas, increasing marginal lands are being brought under the plough leading to a substantial rise in the sown area while leading to a loss in grazing lands. Moreover, people have the tendency to produce more food on shrinking plots and then turn to intensive agricultural techniques and over-cropping which makes soil face a constant danger of erosion and depletion. Another significant implication of over cropping is that it reduces the available organic matter in the soil. Humus is lost and the ability of soil to retain water is reduced. This speeds precipitation runoff, increasing the risk of flooding and erosion thus making the area more susceptible to drought and further processes of soil erosion and desertification.

To add to the problem of the growing population and land requirements of the densely populated area, the diminishing grazing land also leads to the inevitable overexploitation of the ever-shrinking grazing areas. As more lands are being trampled on by cattle and livestock, the soil becomes increasingly more compact, making it harder for any vegetation to grow on. Once the land is free of vegetation that would otherwise have held the topsoil layer, it becomes prone to natural erosive processes such as wind or water. Grazing pressures can contribute to accelerated nutrient losses, rates of erosion, land degradation in the form of soil damage and reduced plant yield [21-23].

Another driver of soil erosion in India is the mine spoils. Mine spoils left to nature may take centuries to develop any vegetation cover [24]. In Rajasthan, mining leases are spread over an area of 0.9 million ha of which 0.1 ha is estimated to be in forest land [25]. The main physical problems of mine spoils are the shallow substrate of soil as well as large cavities in the coarse-grained substrate with a coarse texture and high stone content [26]. Chemically, mine spoils lack nitrogen and phosphorus due to lack of organic matter, low cation capacity and base saturation [27]. In contrast, humus, the end product of organic decomposition, has the highest cation capacity value because organic matter colloids have large quantities of negative charges. Humus and decomposed organic matter act as binding agents for the soil, reducing its erodibility. And when organic matter and humus is absent, this represents unfavorable conditions for the regrowth of vegetables and contributes to the unproductivity of land after mining which leaves the soil exposed and prone to degradation. Erosion is expected to inhibit the development of soil structure [28] because stable aggregate can build up only if natural or anthropogenic disturbances are not too frequent [29] and consequently when losses of finer particles and cementing agents, such as soil organic matter (SOM) and inorganic binding agents, are limited [30] aggregation can be considered as proxy for soil erosion[30]-[31].

Furthermore, the severity of water erosion is maximum in central highlands including the Aravali landscape. Water causes loss of topsoil through sheet and rill erosion resulting in reduced plant growth and compromising the sustainability of the land as transported nutrients are often high in nutrients and fine particles. Additionally, water also causes terrain deformation through gully and ravine land. Ravines can be aggravated by soil erosion usually caused by the overflowing of the water body. The adjacent lands are eroded and over time, as ravines widen, it can render land uncultivable and infertile with the erosion of topsoil and removal of essential minerals into rivers.

Soil biodiversity and fertility have been found to decrease with depth as the amount and diversity of nutrients and the concentrations of oxygen become limiting[32-33]The soil surface is often covered by litter from above ground communities and it is this top soil layer that contains the highest concentrations of soil organic matter[33]-[34].Reference [35] provided evidence that on a continental scale, the positive effects of soil biodiversity-fertility and fertility-above-ground productivity are limited to topsoil(above 20cm depth).Co-occurrence of resources from above ground community with high soil biodiversity supports strong links between soil biodiversity, soil fertility and plant productivity at top soil level and reduction in soil biodiversity and fertility with soil depth can break the link between soil biodiversity, fertility and plant productivity in the subsoil. Thus, as the described processes take place over many years over agricultural lands of Rajasthan, further reduction in top soil layer also reduces biodiversity hence affecting the ecology and productivity of the region.

IMPLICATIONS ON AGRICULTURAL LAND

Table II. Land Utilization in Rajasthan[37]

S.No	Classification	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	Quinquennial Average
1	Geographical area(for land utilisation purpose)	34266	34265	34270	34270	34224	34259(100)
s	(i)Forest	2675	2698	2727	2728	2735	2712.6(7.92)
	(ii)Land put to non Agricultural uses	1823	1835	1847	1970	1976	1890.2(5.52)
	(iii)Barren & Unculturable land	2439	2427	2418	2295	2292	2374.2(6.93)
	(iv)Permanent pastures & other grazing lands	1708	1706	1703	1699	1697	1702.6(4.97)
	(v)Land under misc. Trees crops & grove	21	20	16	18	17	18.4(0.05)
	(vi)Culturable Waste	4590	4611	4573	4336	4475	4517.0(13.18)
	(vii)Current Fallow	1910	1939	1724	1565	2055	1838.6(5.37)
	(viii)Other fallow land	2264	2265	2167	2108	2048	2170.4(6.34)
	(ix)Net area sown	16836	16764	17065	17551	16974	17038.0(49.63)
2.	Area sown more than once	4863	4770	5113	5220	4770	4947.2(14.44)
3.	Total cropped area	21699	21534	22208	22771	21745	21991.4(64.19)

Land degradation refers to the reduction in productivity of land caused by wind and water erosion of soil, loss of soil humus, depletion of soil nutrients, secondary salinization, diminution and deterioration of vegetation cover as well as loss of biodiversity while desertification reduces the ability of the land to support plant life [36].

In Rajasthan, 67% of the area is affected by land degradation and/or desertification. Wind erosion (44.2%) is the maximum contributor followed by water (11.2%), vegetal degradation (6.25%) and salinization (1.07%) [37]

The Aeolian (wind-driven) geomorphic process is more prominent in the western part while fluvial (water-driven) geomorphic process is more dominant in the eastern part. The distribution of these processes is influenced by rainfall distribution which decreases from east to west [38]

The most productive topsoil layer, which contains 50% of the most important nutrients such as phosphorus and potassium, is blown or washed away rather quickly during desertification due to lack of vegetation cover and hence both soil nutrients and organic matter are lost. If degraded land is used for grazing, it leads to a quick reduction in plant species and the total degradation increases and spreads. Soil becomes dry and hardens which makes it difficult for rainfall to penetrate the soil surface due to the arid condition of the soil. As a result of these sustained erosive processes, the conditions of the soil become unfavorable and plants grown on these damaged soil fail to produce sufficient yield output [36].

As shown by table 2, the area sown more than once is only 14.44% which represents low sustainability of the soil and poor irrigation facility of the state.

Wind erosion, which is the greatest contributor to land degradation and desertification in Rajasthan, is harmful to both the area where the topsoil has been blown away as well as where the sand has deposited. The blowing away of the topsoil with its nutrients leaves a poor nutrient coarser substrate. The problem is exemplified in agricultural fields which are ploughed before or during the summer high wind because they remain without any protective vegetation cover or mulch.The blowing of the wind also causes injury to young crops and those with a shallow root system. The sandblasting during sandstorms can expose shallow roots by erosion of sediments and lead to the eventual death of the plant. In the area where deposition occurs, small crops are buried under the sand and fail to survive [38]

Furthermore,land use is an important factor affecting soil organic carbon(SOC) stocks[39]-[40].Maintaining carbon storage in soil would help improve soil quality, promote sustainable environment restoration and ecological security[41].Reference[42] showed that tillage and soil erosion leads to loss of SOC and the distribution of SOC on the slope changes significantly with soil erosion.Additionally, Reference [43] showed that conversion of natural forests to economic forest increase soil erosion and impacts ecology.Reference [44] found that the total area under agricultural land was increased by 32.14% while that of forest was decreased by 23.14% during the time period of 1993-2014 in the Pushkar Valley region of Rajasthan. Cited research also observed that the overall land use change showed during 1993-2003 and 2003-2014, 7% of forest area was converted to agricultural land and about 15% changes occurred among agricultural land.The study concluded that the internal trading of land use area during the 10-year period (1993–2003) led to net loss of SOC stock by 8.29 Mt C and land use change during 11-year period (2003–2014) caused net loss of SOC by 2.76 Mt C. As desertification and soil coarseness leads to reduction in Net Primary Production (NPP), SOC and ability of soil to retain nutrients.This in turn lowers the productivity of land.

Rajasthan is one of the most populated deserts in the world. The population in Western Rajasthan alone has increased manifold from the 1901 census shown in Fig.1. The growth is so much such that the decadal growth rate here is higher than that of the country as a whole.

Rajasthan is a predominantly agrarian state with about 70% of the population depending on agriculture and associated activities. The population pressure of both humans and cattle in Rajasthan also puts great pressure on the agricultural land. As per the 2011 Census, the population of the state is 68.62 million which constitutes 5.67% of the total population of India. According to the livestock Census of 2007, the state also holds the second most population of livestock (56.66 million) in the country. According to [45], the total livestock population in the last five and a half decade was almost doubled in the state of Rajasthan.Thus the growing population of both humans and cattle has disrupted the traditional system of land usage. Agricultural activities can extend to fringe lands which are more prone to the process of land degradation. The extension of agricultural activities to more vulnerable land in turn reduces vegetation cover. As a result of cattle feeding and trampling on these marginal lands, the soil becomes dry and hardens and accelerates the arid condition of the region.

The impact of soil erosion and desertification on agricultural land of Rajasthan is a continuous process enhanced by population migration of cattle and humans in search for more productive land. As forest areas are slowly converted to grazing land, SOC stock reduces, soil becomes coarser from the effects of wind erosion and NPP of the land reduces. These changes have therefore led to a reduction in the productivity of the region. As shown in Table 2, the quinquennial average of barren and unculturable land is 6.93 percent, almost 2 percent greater than the average for permanent pastures and other grazing land.

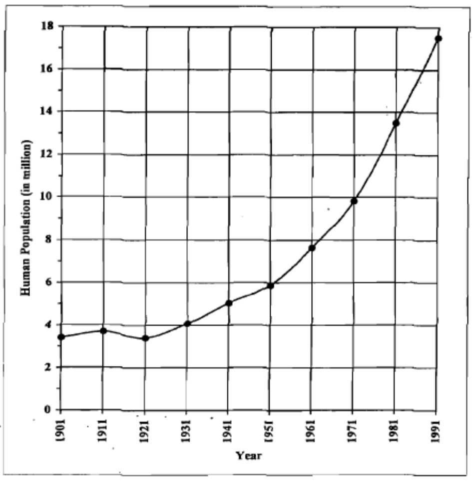

Fig. 1. Growth of Human population in western Rajasthan(1901-1991)[38]

CONCLUSION

Desertification and soil erosion are threats to agricultural land in Rajasthan. The loss of topsoil by wind and other erosive processes could contribute to the diminishing returns from land. The magnitude of the problem is further enhanced by Rajasthan's large population of both humans (Fig.1) and cattle. As populations grow, the demand for food production has also increased and increased grazing pressures could contribute to accelerated nutrient losses, rates of erosion, land degradation in the form of soil damage and reduced plant yield[21]-[23].

As abundance of soil resources are depleted, the ecological stability diminishes. Thus, it is of great importance that measures to combat these processes must be implemented. Improved cropland, livestock and grazing land management as in the Voluntary Guidelines for Sustainable soil management [46] are some options aimed at addressing the problems of land degradation and desertification. Some available management options are: crop and animal selection, optimized stocking rates, changed tillage and/or cover crops, land use change from cropland to rangeland, increases in ground cover by vegetation, and protection against wind erosion[47]-[48].Managing stocking rates and grazing can also help prevent the advance of land degradation[49].Strategies like water use efficiency and irrigation would improve soil health by enhancing soil organic matter content thus delivering benefits for prevention or reversal of desertification [50].Using manures, legumes, fodder legumes and cover crops combined with conservation tillage system[48] would help increase ground coverage by vegetation and reduce losses from wind erosion.Desertification could also be reduced if bare lands are converted to agriculture and forests from non-forests to forests [51]

FUTURE RESEARCH

As the present study has identified the exploitation of grazing land as a major contributor to desertification and soil erosion in Rajasthan, it is noteworthy to consider examining measures that reduce overgrazing. As a major sector of the state is involved in agricultural production, strict rules could be introduced to close common grounds to prevent cattle from grazing. These efforts would allow plantlets to grow into vegetation cover thereby eliminating further risk of soil erosion. However, these measures should consider the livelihood of the farming community and how such measures could affect the biodiversity and ecology as well.

Furthermore, the loss of Soil Organic Carbon (SOC) stocks and topsoil is a major concern during desertification and soil erosion. The primary measure currently in use by the government to combat desertification is integrated watershed management. Research that examines the comparative effectiveness of these measures with other measures such as afforestation, restoration of bare land to forests, or afforestation could be considered. Sustainable practices that restore SOC would aid in increasing the productivity of land in the future and afforestation campaigns in local communities with large areas of barren land would protect the loss of topsoil and nutrients.

Additionally, research that produces qualitative data on Nitrogen, Carbon, and other essential soil nutrients would help evaluate effectiveness of measures to combat desertification and soil erosion especially as such data are not commonly available. Data before and after measures to combat erosive processes were implemented would aid in the assessment of the productivity of land.

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