Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Land Degrdation, Causes, Implications, and Sustainable Management in Arid and Semi-Arid Regions: A Case Study of Egypt

Mohammed Bello Abdullahi [1,2]; **AbdelHamid El-Naggar**[2]; **Mahmoud Omar**[2]; **Animashaun Iyanda Murtala**[3]; **Mohammed Lawal**[4] and **Ahmed Mosa**[2]*

[1] *Department of Crop Production, Ibrahim Badamasi Babangida University, Lapai, Nigeria*
[2] *Soils Department, Faculty of Agriculture, Mansoura University, 35516 Mansoura, Egypt*
[3] *Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria*
[4] *Department of Civil Engineering, Niger State Polytechnics, Zungeru, Nigeria*

THIS REVIEW focuses on the main causes, effects and governmental management practices of soils in Egypt subjected to degradation threats. Land degradation became a global concern threatening food security and the ecosystem since it has a significant impact on the environment and agriculture. The major causes of degradation are alteration in climatic conditions, overgrazing, salinization, deforestation, depletion of soil organic matter content, desertification, waterlogging, inappropriate agronomic practices and erosion. It is paramount to reduce these causative factors in order to adequately manage the situation. The effects of these factors may lead to loss of ecosystem, biodiversity and agricultural yield/output. We can manage and improve the well-being of our soils in Egypt through afforestation, managing vegetation cover, soil reclamation, optimizing agricultural practices (e.g. tillage, irrigation and fertilization), avoidance of crop residues removal and application of organic matter to the farmland. Additionally, organic farming can be a substitute in keeping our land safe from degradation. The outstanding features of GIS and remote sensing, which include: field wide view, inexpensive costs, instantaneous data capturing, and sporadic imagery is now widely applied in the studies of land degradation due to its timeliness, coverage and efficiency. Future research in this area of study should empjasis on developing modern soil sensors, which will be connected with sattalite data, to predict the futute alterations in soil ecosystems and potetials of land degradation.

Keywords: Sustainable Management**;** Land Degradation; Agriculture; Environment; GIS and Remote sensing

1. Introduction

Land degradation (LD) is an environmental process associated with the decline in productive capacity of soils as a result of soil erosion and/or any other alterations in the hydrological, biological, physical and chemical properties of the soil. Land use alterations by anthropogenic activities have had inconsistent impacts on the Earth's surface taking into consideration that soil is a non-renewable natural resource (Haregeweyn *et al.*, 2023). Many locations throughout the world are currently losing their fertile topsoil due to several natural causes (wind, water, and climate influences) and anthropogenic activities (e.g. unsustainable agricultural practises and intensive tillage that induced erosion) (Heffer and Prud'homme, 2014; Ferreira *et al.*, 2022). More than 90% of the world's topsoil is threatened by land degradation, potentially exacerbating negative consequences such as reduced crop production and a negative impact on food security as the world's population grows (Beillouin *et al.*, 2022; Wang, 2022). Negative impacts of land degradation are numerous, these may include; loss in soil organic matter content, soil erosion, soil compaction, desertification, salinization, deforestation (Turner *et al.*, 2016). Land degradation are associated with tremendous impacts on land productivity, biodiversity, soils flora/fauna that affects human livelihood (Mohamed *et al.*, 2019; AbdelRahman and Arafat, 2020; El-Rawy *et al.*, 2020; AbdelRahman *et al.*, 2022; AbdelRahman, 2023). Land degradation due to accelerated and combined effects of urbanisation (deforestation), inappropriate agricultural activities (e.g. intensification of land management practises and overgrazing) has exacerbated the negative impacts on severe weather warnings (e.g. high temperature, heat islands and

---

*Corresponding author e-mail: ahmedmosa@mans.edu.eg

Received: 17/08/2023; Accepted: 04/09/2023
DOI: 10.21608/EJSS.2023.230986.1647

dust storms), coastal erosion and drought-induced salinisation (Moghanm *et al.*, 2020; Molnárová *et al.*, 2023; Mosa *et al.*, 2023b). Because of the unequal distribution of global natural resources and huge regional variances, urbanisation growth produces serious arable land resource shortages in crucial locations (Wang, 2022). According to United Nations Convention to Combat Desertification, natural causes including drought, a reduction in vegetation and biological production exacerbate degradation of land in dryland environment (Stringer, 2008). Land degradation can have a wide range of consequences for human health. Land is eroding; constrained agricultural production, shortage of water bodies, and human beings are compelled to relocate to vulnerable regions.

As a result, a global approach is required to promote consciousness on the economic penalties of land degradation and encourage good management of land resources. It should provide a comprehensive approach to examining economics of land degradation, and making its budget a fundamental aspect of policy and decision-making approaches by improving the political and general consciousness on the value and well-being of land and land bionetworks. Approximately 30% of all productive land on earth has degraded due to the aforementioned processes during the last few decades (AbdelRahman, 2023). Developing countries are particularly susceptible to land degradation due to the lack of capital and infrastructural capabilities to deal with these menaces and apply sustainable land management practice. Degraded lands also have an impact on food security universally: universal agricultural output might decline by 12% over the next two decades (Thomas *et al.*, 2013). Consequently, food costs will rise by up to thirty percent on average as a result of this. The Economy of Land Degradation Initiative estimated the yearly cost of land degradation to be €3.4T. LD, combined with high population growth and an oversupply of other products of land management i.e biofuels which causes food scarcity/insecurity, inadequate clean water, severe weather conditions and high sensitivity to climate change (Thomas *et al.*, 2013).

A number of problems associated with soil and natural resources are been confronted by the farmers in dry farming areas, which prevent agricultural productivity. Among the problems confronted by small farm holders is inadequate information on soil nutrients and favourable land management practices. Besides, secondary soil salinization showed a progressive increase in irrigated agriculture systems due to the intensive utilization of low-quality water resources. However, in rainfed agricultural systems, soil degradation and fertility depletion might cause by other causes (natural sources in particular) including wind/water erosion and/or rainfall depletion. With soil as the base for agricultural production, small farm holders continue to be the focus on what they will do to restore the productivity of soil in long-term period. Hence, there is a need to encourage the recovery of the already impoverished agricultural lands and intensify continuous production through several management toolkits including (i) efficient water utilization, (ii) improved water and nutrient-supply potentials of soil, (iii) recovery of degraded/salinized farms, (iv) ensuring appropriate application of agricultural amendments (e.g. organic amendments and polymers) and (v) utilization of mulching systems using synthetic products (plastic mulching films) and agricultural byproducts (e.g. rice straw, husk, rice bran etc) (Mosa *et al.*, 2020; El-Naggar *et al.*, 2022a; Tiemann and Douxchamps, 2023; Yang *et al.*, 2023). As a result, training programs on land management should be addressed in Egypt and most African continent to synthesis a coherent approach for facing land degradation scenarios. In this form of program, engaging stakeholders of such programs is crucial. By so doing, it will assist on improving knowledge of best practises on farm-scale activities for combating soil degradation, as well as promoting awareness on integrated soil management and sustainable agricultural systems. Furthermore, it will aid in the diffusion of knowledge with subjects specifically developed to transmit scientific knowledge from research laboratory to fields and field to laboratory. Subsequently, these training programs will open prospects for the exchange of thoughts on different issues and communication links with other stakeholders will be developed. This review focuses on the causes of

The main aim of this review is to synthesis a coherent a state-of-the-art review about causes, implications and sustainable management of soils located in arid and semi-arid regions (particularly in Egypt as a representative model) in order develop a decision making framework to address this challenge in the future.

2. The concept of land degradation

The idea of land degradation varies in its emphasis. However, they have substantial repercussions regardless of the kind of LD. It is estimated to costs $300 billion (Nkonya *et al.*, 2016; Feng *et al.*, 2022), and it results in the losses of various ecosystem services (Pereira, 2020). As mentioned earlier, land degradation as a complicated phenomenon is caused by a variety of natural, biological, as well as chemical components. Soil erosion being a natural phenomenon, dramatically exacerbated its severity by anthropogenic activities (Borrelli *et al.*, 2020; Mosa *et al.*, 2022b; Mortada *et al.*, 2023; Mosa *et al.*, 2023a). Figure one gives an overview regarding causes of LD. Increased irrigation is one of the most critical concerns associated with soil change. In view of this, salt accumulation in soil matrix due to intensive utilization of low-quality irrigation resources is a common problem in irrigated-agricultural systems in arid and semi-arid regions, which translates to long-term decline in soil fertility and quality indices (Janmaat, 2005).According to former reports, anthropogenic activities have damaged to varied degrees 10% of universal total earth surface (Fenta *et al.*, 2020; AbdelRahman, 2023). Water erosion, wind erosion, chemical erosion (water saturation and salinity), overgrazing, deforestation, inappropriate agronomic practices, land abuse and other illogical events were the main reasons responsible for damages in these degraded soils. Land degradation in parched places (i.e dry sub-humid, semi-arid and arid), is described as decline in productive capacity of land and loss of biodiversity resulting from natural or anthropogenic factors. Land degradation was expected to moderately affect 30% of irrigated dryland areas, 47% of farmland, and 73% of rangeland (AbdelRahman, 2023).

Land degradation is part of the components that destroys the Earth's natural environment and deteriorates land plantation cover. It contributes considerably to global biodiversity loss, loss of soil quality/productivity and reduction in soil organic matter reserves globally, disrupting terrestrial biochemical transformation. Atmospheric carbon dioxide emission is increased resulting from LD by reducing the number of plants that sequestrate atmospheric carbon dioxide into their bodies (Xu *et al.*, 2023). In addition, removal of the plant cover might cause large overflows of colloidal components of soil (e.g. fine clay, silt and organic matter) into water bodies resulting in a reduction in soil fertility. This may also result in high sandstorms and a low groundwater recharge through the surface of the earth and potential of non-point sources pollution. Soil composition and management influence agricultural land productivity. Soil comprises organic, bio-organic and mineral components in a dynamic natural equilibrium developed over millions of years of geological time. However, soil degradation may compromise this balance (AbdelRahman, 2023). Some approaches of protecting soils from degradation include: improving water retention in soil (Marczak *et al.*, 2022), preventing denudation (Saljnikov *et al.*, 2022), maintaining living organisms in the soil both those that build up soil and those that releases nutrients (Singh *et al.*, 2011) and sustaining permanent soil cultivation (Delgado and Gantzer, 2015).

3. The climate of Egypt

Egypt's climate is influenced by a number of elements, the most paramount of them are its geographical location, physical features, surrounding water bodies, general pressure system and depressions. Housing and Building Research Centre (HBRC) reported that, all of the aforementioned contributed to the division of Egypt into eight distinct climatic zones (Sayed *et al.*, 2014). The location of Egypt is in arid zone (the Sahara), with exception of the north, that falls within the green temperate zone and have Mediterranean climatic pattern (Fig. 1), which characterised by hotness and dryness in period of summer and moderation in winter period and slight rainfall in the coastal zones. The climate of Egypt is divided into hot dry summer and moderate winter seasons: the hot dry summer that lasts from early May to late October, and the moderate winter with little rain that lasts from November to April (AbdelRahman, 2023).

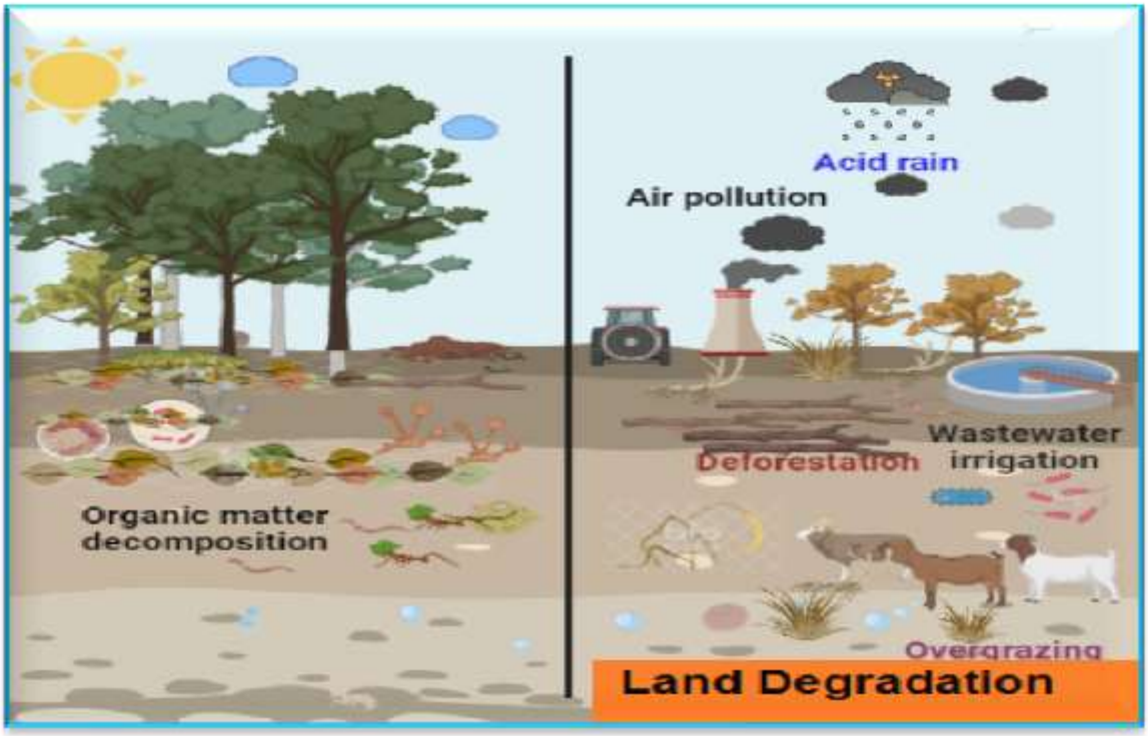

Fig. 1. An overview of land degradation.

Table 1. Data of average temperature in Egypt.

Months	Average Temperature(°C)	Precipitation (mm)
January	19.4	70
February	20.6	35
March	23.9	20
April	28.3	2
May	32.2	1
June	35.0	0
July	35.0	0
August	35.0	1
September	33.3	1
October	30.0	15
November	25.0	35
December	20.6	55

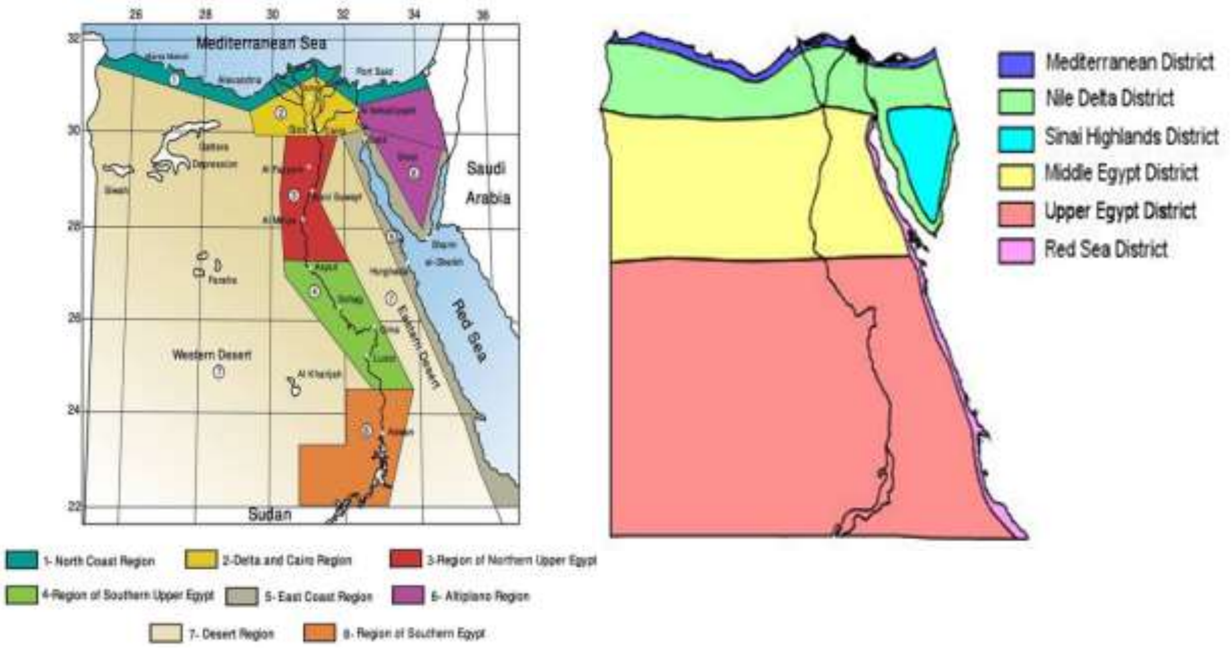

Fig. 2. Egypt climatic zones classification HBRC, After (Salem et al., 2016, Hamed et al., 2022, AbdelRahman, 2023).

4. Status of land in Egypt

Egypt's present agricultural land use is demonstrated to be one of the most rapidly expanding agricultural frameworks on the earth. This widespread is a circumstance in which it is exposed to mini evolutionary forces, and the shift requires extra contributions to create the vegetation, such as agrochemicals, water system, preparation, and so on. This has resulted in a justifiable inequality between land development and management, particularly now that the small farm holders are majority who cannot utilise persuasive ways of assistance to safeguard their farms. National Programme to Combat Desertification (Unccd, 2005), reported that Egypt Land degradation process in Egypt refers to the destruction of the biological productivity of land, that could lead to conversion of farms or pastures that are rainfed or irrigated-dependent to a semi-desert; has an extensive grazing area estimated at 4M hectares (9.5M feddans) despite of its developed topography, which includes 333 hectares (1.4M feddans) in the Halayeb-Shalateen polygon and 1,309 hectares (5.5M feddans) on the northwest coastal zone and 619 hectares (2.6M feddans) in different parts of Sinai Peninsula zone: - northern lands and valleys, the centre and southwestern Sinai. In terms of grazing, the present condition of Egypt's rangelands is quite limited. Almost half of these lands are categorised as very poor, 35% as fair, and 15% as acceptable.

5. Land degradation in Egypt

consequently, resulting in low productivity (Mohamed *et al.*, 2019; AbdelRahman, 2023). Egypt as proclaimed by the United Nation “the world first desert nation” in the 70s because of the extreme circumstances, which characterise the dry area, as it encompasses around 86 percent of very dry areas and 14 percent of dry areas. Egypt has an estimated total area of nearly 1M km^2 (238M feddans) in northeast Africa in which the populations are concentrated in an area of approximately 3,333 hectares (14M feddans) or less than 6 percent of entire region. In Egypt, the area of farm lands is weighed to be approximately 1,952 hectares (8.2M feddans) or 3.45 percent the entire region, with 1,357 hectares (5.7M feddans) of ancient irrigated farms in the Delta/Valley, 523 hectares (2.2M feddans) of recovered irrigated farms, and approximately 714 hectares (3M feddans) on the eastern and western coasts rainfed farming (Abdelhafez *et al.*, 2020). The United Nations Convention to Combat Desertification, ranked Egypt first worldwide in LD, that takes place because of the integration of climatic, human, biological as well as geological factors that causes the land's biological and physico-chemical constituents' destruction in dry and semi-dry areas (Unit, 2005). According to Food and Agriculture Organisation of United Nations (FAO) publication guidelines of 2010, dry areas have a great influence on natural biodiversity. Egypt's most degraded areas are classified into four zones namely: Eastern desert zone, Western desert zone, Sinai-peninsula zone and Nile valley and its Delta zone (Omran and Negm, 2020). Each with its own set of reasons, the zone suffers from varied degree of degradation because of soil salinity, rising groundwater tables, and construction on agricultural lands (El-Ramady *et al.*, 2018). Whereas LD in other areas was naturally caused, flood from water erosion or strong winds.

Egypt lost approximately 476 hectares (1.9 million feddans) in the northern and eastern regions of the delta as a result of soil degradation. Urbanisation, salinization of agricultural areas, pollution, depletion of soil nutrients, soil compaction, land erosion and formation of sand dunes all contribute to the destruction of approximately 30 thousand acres of the most important agronomic farm areas each year. In the valley as well as the delta where irrigation farming is practiced suffer from the consequences of irrigation. The improper drainage system caused groundwater to increase and salts to accumulate in soil matrix, resulting in reduced soil productivity. The oasis and western parts of Lake Nasser, Assiut, Minya and North Sinai are degraded due to sand dunes, agrochemicals, residues from industries, waste water effluents and loss of soil nutrients. Other circumstances, such as salty irrigation water or critical increase in groundwater volume, worsen the problems of water and salt accumulation in the lands (Wang *et al.*, 2016). More so, in the Western part of Sahara oasis the poor-quality irrigation water and degradation is becoming alarming, particularly Siwa Oasis, because of the waste of high quantity of irrigation water resulting from the absence of drainage infrastructure.

6. Problems and Pressure on land resources in Egypt

In Egypt, the main scenario of soil degradation is related with waterlogging, salinity, surface and groundwater pollution, deterioration of inundated areas and soil fragmentation, which reveals the inadequacy of agricultural land management. In the same vein, valuable land areas are susceptible to a variety of pressure and circumstances. This contributes to exploitation of land as well as the impediment of economic development, which guarantees reasonable living standard in the environment. The tasks that promote soil deterioration are explained below.

6.1 Urbanization

The encroachment of urbanization on best agronomic areas is considered among the weightiest degradation phenomenon since it is a complete and comprehensive damage of the land's core function in the production of biomass, which include crops, clothing raw materials and medicinal raw materials. For instance, the annual increase in urbanization in Dakahlia Governorate was approximately 2.54 and 4.01 km^2 annually during the period from 1984-2002 and 2002-2011, respectively; however, this rate increased up to 48.00 km^2 per year during the period between 2011 and 2014 (Elnaggar *et al.*, 2020).

Cultivated areas in Damietta Governorate showed also severe degradation due to urban sprawl, fertility deteriorations and salinity/sodicity hazards (Elnaggar, 2020).

In another study, satellite data and geographical information system (GIS) modelling capabilities pointed to a reduction of about 5.5% in two sites of Fayoum Governorate (Sinnuris and Gharaq) given the fast progress of urbanization activities (Abdelhaleem *et al.*, 2021). Therefore, restricted laws and special programs should be undertaken in order to prevent the progressive degradation of Egypt's soil resources. The law signed in 2005 has resolved this situation, which reduced the percentage of intrusion of urbanization against productive farm lands from roughly 7.14 hectares (30,000 feddans) to 1.19 hectares (5000 feddans). Destroying the heritage of some touristic locations in Egypt (e.g. El-Mokattam and Abu Roash) is also a reflection of progressive growth in urbanization. In view of this, satellite images interpretation pointed to destruction and/or damages of many unique objects in these important places following the fast urbanization during the period 2000–2017 (1.4 and 3.4 times in El-Mokattam and Abu Roash, respectively) (AbdelMaksoud *et al.*, 2018).

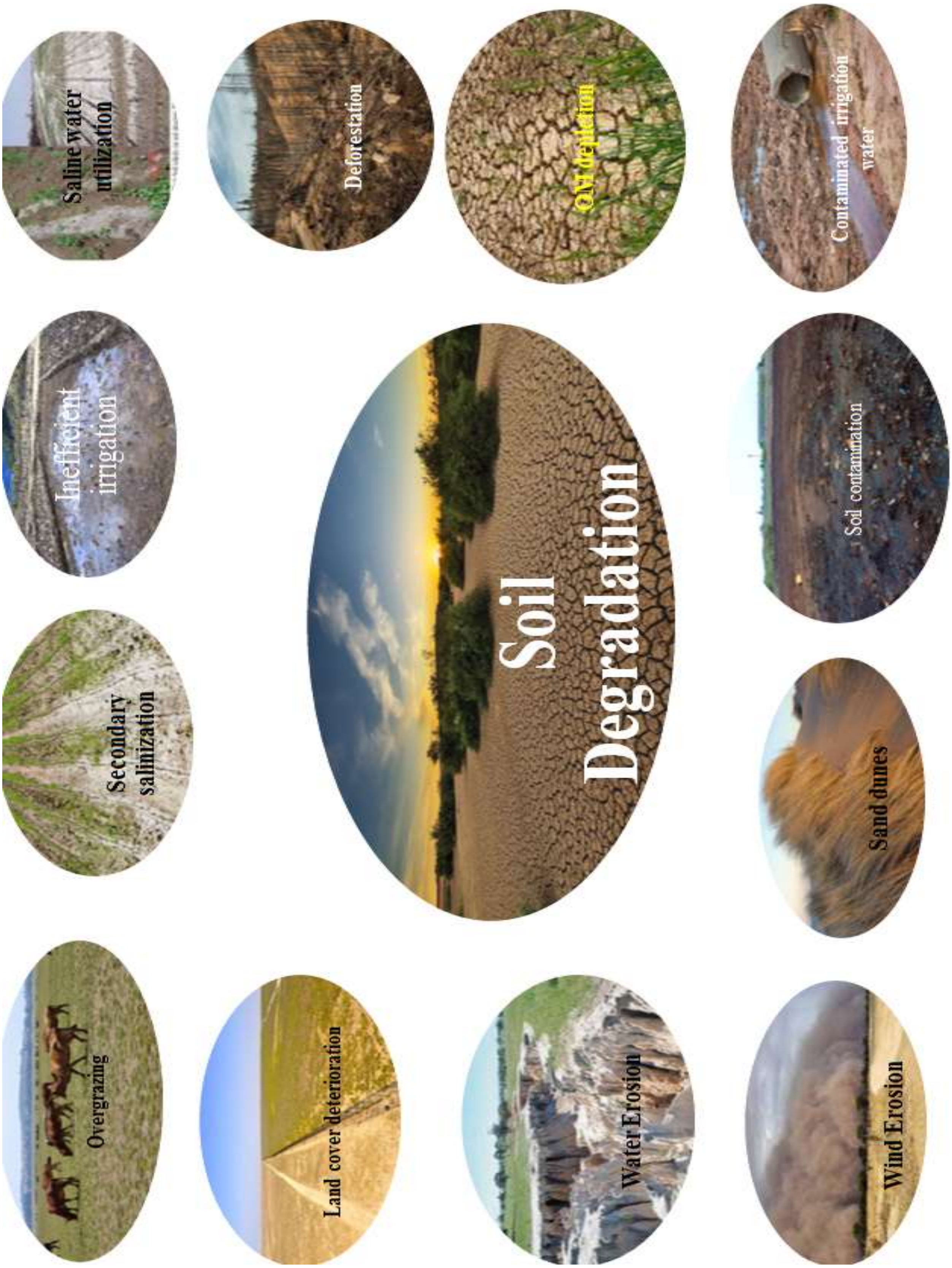

Fig. 3: Main causes of soil degradation.

6.2 Contamination of arable land

In Egypt, pollution is one among the fundamental causes of LD, threatening vast sections of productive fields, human beings and animals due to corrupt land and water management, as well as human activities in the villages. For as long Nile River remain the sole provider of irrigation water in Egypt, pollution will continue to originate due to the high loads of pollutants, in addition to recycling water from farm drainage, which contain different types of fertiliser/agrochemicals residuals (Abdel-Satar *et al.*, 2017; El-Naggar *et al.*, 2022b; Mosa *et al.*, 2022a). Nutrients produce eutrophication of the coastal ocean and estuarine environment, resulting in "red tides" on a regular basis and impacting on the soil during irrigation. The physical extent and adversity of nutrient pollution have progressively increased during the last few decades. Agricultural fertilisers are the primary source of nutrients, and their use has expanded dramatically during the last 20 years (El-Ghamry et al., 2021). Another source of pollution in this area is atmospheric deposition, and while determining the amount with any precision is difficult, all studies indicate that it is significant (such as sulphur oxides, nitrogen oxides, heavy metals etc) (Li and Daler, 2004; Amodio et al.,2014). In addition, agriculture is the largest provider of non-point nitrogen sources, accounting for an estimated 70% of total input to inland surface waters (DEFRA, 2002). According to a recent GIWA in the Black Sea, agriculture provides 35% of overall eutrophication, whereas urbanisation 35%, energy production 20% and transportation contribute 10% (Borysova et al., 2005).

6.3 Salinization of agricultural land

Salinization is among the utmost prominent phenomenon of farmland deterioration in Egypt, as a result of inappropriate irrigation management, which uses traditional irrigation method with a productivity of ≤ 60 percent in mainstream of the nations irrigated farms. The intensive utilization of drainage water resources that contain high levels of salinity could be another reason for soil salinization as well. In addition, there is an intense draw of water from water intrusion from coastal areas located near the Mediterranean Sea. Furthermore, the progressive increase of water table due to the inadequate irrigation system led to the secondary salinization of huge areas of cultivated soils. Accordingly, several reports have suggested that over 30 percent of Egypt's irrigated areas are salty soil (Hossain *et al.*, 2020). High exchangeable Na^+ in sodic soils causes swelling and/or dispersion of soil colloids, resulting in soil structure failure. These consequences result in low water permeability/infiltration, bad aeration, poor respiration/penetration of root, formation of hard crust/compacted subsurface layers (Priori, 2021). Soil organic matter is dissolved by high pH in sodic soils, resulting in organic matter loss. The growth of plants on sodic soils is bad because of low physical conditions of the soil, low available mineral nutrient, uneven nutrient absorption, and harmful effect of most notably the Na^+ ion (Gondek, 2020). According to Jamil et al., (2011), salinity would destroy more than half of the world's arable land by 2050. The issue of ensuring food security for our growing population is becoming more worrisome. This challenge must be tackled in light of shifting mode of consumption, the effects of climate change and the degradation of our non-renewable land and water resources.

6.4 Physical deterioration of the soil

In rural farming community, excessive exploitation take place due to intensive farming practices, with the goal of completing the necessary operations, such as ploughing, control of pest and harvesting under unfavourable situation in many cases using unsuitable implements. Consequently, resulting to collapse of soil structure and the appearance of plough pans, limiting growth and deepening of plant roots as well as decreasing agricultural drainage efficiency, particularly in some areas of the north and northeast Delta where production is estimated to have decreased to approximately 8 percent (Mohamed, 2017).

The application of no-tillage system is an efficient management system for controlling soil compaction and improving soil quality characteristics. However, the intensive cultivation system in most African countries (Egypt in particular) led to deteriorative impacts of soil physical properties. The growing concern of using tillage systems by high machinery weight equipment caused drastic reduction in hydraulic conductivity, which eventually led to soil erosion and sharp decline in crop productivity (Kayombo and Lal, 1993; Hassan *et al.*, 2022).

6.5 Soil fertility depletion

The practice of intensive agriculture, application of excessive quantity of irrigation water, absence of Nile alluvium and high content of mineral nutrients for vegetation after the construction of high dam and reducing organic matter percentage, specifically in recovered areas (constitute approximately 40 percent of total irrigated farms in Egypt). It was reported that approximately 15% of such agricultural lands are rendered unproductive due to deficiency in nourishing mineral nutrients content as well as entire fertility depletion (El-Ghamry *et al.*, 2009; Elnaggar *et al.*, 2016a; Elnaggar *et al.*, 2016b). There are several reasons for the sharp decline in soil fertility including inadequate fertilization programs, intensive cropping systems, removal of crop residuals, tillage systems, inappropriate cropping systems, inadequate irrigation/drainage systems and soil erosion (Aleminew and Alemayehu, 2020). Smallholders’ farmers represent the vast majority of the agriculture association system in Egypt. They tend to apply high amounts of mineral fertilizers to compensate the sharp decline of plant nutrients, which are absorbed by crops. The intensive utilization of mineral fertilizers led to increase soil salinity levels and obstruct the optimal growth of wide range of crops (Alshaal *et al.*, 2017; Aleminew and Alemayehu, 2020). These negative impacts eventually reflect on sharp reductions in soil fertility.

6.6 Sand dunes

Sand dunes occur in regions most susceptible to wind erosion and sedimentation. It was reported that Aeolian deposits cover approximately $1.6x10^5$ km^2, which represent about 16% of the total surface area of Egypt (Misak and Draz, 1997). Agricultural growth and communities, both rural and urban, are threatened by their actions. Among the constrains of agricultural development in Sinai (soil reclamation projects in particular) is the migration of aeolian sand dunes (approximately 5000 Km^2 of the coastal zone) that might also cause severe damage to the infrastructure (e.g. irrigation and drainage structures, road network systems) and human settlements. In view of this, aeolian sands migration caused longitudinal dunes movement by rates of 2.25 and 13 $m\ y^{-1}$ in south of Bir El Abd and Wadi El Gady areas (Philip *et al.*)2004). Active dunes are also the most hazardous, intimidating developments in places like the Wadi Al Rayan and Fayoum (880 km^2), north western High Dam Lake (800 km^2), the El-Kharja Oases (400 km^2), the grooves western Beni Swaif, Assyout, and Minya governorates (350 km^2) and west delta (255 km^2) in addition to aforementioned are the eastern delta and northern Sinai, especially in some areas near the path of Al Salam canal (Unccd, 2005).

6.7 Soil erosion

Egypt is located in an adversely dry area extending from North Africa to West Asia. Wind erosion is regarded among the most serious processes of LD covering more than 90 percent of land area in eastern desert, western desert and Sinai in particular. These locations have a fragile environment, absent vegetative protection and serious drought. According to reports, the percentage of wind erosion in Egypt is approximately 5.5 tonnes per hectare per year in oases regions of the western desert and 71-100 tonnes per hectare per year in regions of rainfed farming on the northwest coast with the hazard of wind erosion in these locations ranging from moderate to severe (Wassif, 2002). Water erosion in the north coast, Red Sea, Aqaba Gulf, and south Sinai coasts, as well as some eastern desert valleys, is considered among the most severe LD in these regions during rainy seasons, literatures has shown that water erosion has a low to severe impact on Egyptian lands (Abu-Hashim *et al.*, 2021). Table 1. Shows land degradation in some locations in Egypt. Whereas Table 2. Indicates the loss of arable land due to the effect of land degradation in Sub-Saharan Africa (SSA).

Table 2. Land affected by different types of degradation in various locations and their causes.

Location	Type of Degradation	% Land affected	Causes	Reference
El-Fayoum	Salinity, sodification, waterlogging	39.14	Human activities	(Ali and Abdel Kawy, 2013)
North Nile Delta	Salinity	8.77	Poor drainage system,	(Enar et al., 2021)
	Waterlogging	40.67	Intensive agric.	
	Compaction	31.25		
	Sodicity	91.17		
Damietta	Salinity and Sodicity	76.08	Urban sprawl, Poor drainage, Sea water intrusion	(Elnaggar, 2020; Mohamed et al., 2019)
Northeast Nile Delta	Low Productivity	45.82		(Abdel Kawy and Ali, 2012)
Siwa oasis	Soil salinization, waterlogging	-	Rise of soil water level	(Elnaggar et al., 2017)
Sinai Peninsula	Desertification	47.9	Low vegetation cover, soil quality, wind erosion	(Abdelhameed et al., 2020)
Assiut	Salinity	85	Anthropogenic, Soil properties, Climatic factor	Sayed and El-Desoky, (2019)

Table 3: Types and extent of land degradation in Sub-Saharan Africa.

Type of Land Degradation	Salinization		Water erosion	Wind erosion	Deforestation
Affected Countries	Harsh in Kenya	Tanzania	Countries in East Africa (Kenya, Tanzania, Ethiopia, Malawi, Zambia)	Djibouti, Botswana, Sudan, Niger, Mali, South Africa, Eritrea, Chad	Hotspots: Togo (-4.5%), Burundi (-5.2%), Zimbabwe (-1.7%) Comoros (-7%), Uganda (-2.2%), Nigeria (-3.3%)
Land Affected	30%	-27%	46%	38%	0.7% of yearly change of woodland area and forest in south and east Africa
Major Causes	Poor water management		Agric. practices, Deforestation, Overgrazing,	Deforestation and Overgrazing	Agric. practices, Deforestation, Overgrazing,

These reports were extracted from (Kirui and Mirzabaev, 2014)

7. Attempts by Egyptian Government to combat Land degradation

Because land degradation neutrality (LDN) is a "Sustainable Development Goal" (SDG), participating in LDN contributes significantly to the attainment of multiple SDG targets while also generating economic and social advantages.

The United Nations General Assembly adopted "The 2030 Agenda for Sustainable Development" in September 2015, which included 17 Sustainable SDGs and 169 targets. SDG 15 encourages countries to restore, maintain and promote sustainable use of ecosystems, sustainably manage forests, combat desertification, pause and reverse biodiversity loss as well as land degradation.

The goal of Target 15.3 is to "combat desertification, restore degraded land including land affected by drought/floods, desertification and strive to achieve a land degradation neutral world" by 2030. The indicator used to assess success of SDG target 15.3 depends on calculating the percentage of deteriorated land divided by total land area. As a result, in October 2015, the nation participants developed voluntary targets for LDN and include them into UNCCD National Action Programme (NAPs). In view of this, Egypt's NAP was adopted in 2005 and 2015.

The Land Degradation Neutrality Target Setting Programme (LDN TSP) gave an important privilege for all stakeholders in Egypt to develop a leveraging plan. LDN target setting is a governmental-led process headed by the UNCCD. At the national level, the Ministry of Agriculture and Land Reclamation assisted with the process is the LDN Target Setting Programme team from the Global Mechanism and the UNCCD secretariat.

To develop a national LDN leverage plan, it is necessary to assess the "LDN TSP" leverage opportunities, with the top priority to improve the productivity of approximately 3.0 million feddan affected by soil salinity and alkalinity and alleviating the effects of soil erosion on the borders of Nile valley and delta

Promoting the sustainable use of land resources necessitates the participation of different segments and stakeholders in the LDN TSP leverage plan, including direct stakeholders such as land users, private service providers, and governmental agencies at the national and sub-national levels, national and international research institutes, civil society organisations (CSOs), and development partners to provide financial and technical assistance to stakeholders.

According to the Egyptian Final Country's Report of the Land Degradation Neutrality (LND) Target Setting Programme (TSP), (2018), the LDN TSP has concluded the following key strategic implementation actions/measures:

"1. Establishment of specific LDN related administration, 2. Establishment of LDN monitoring systems as targeted in the NAP (National Action Programme), 3. Obtaining funds through national ministerial budgets and/or other new mechanisms such as taxes, penalties, payment for ecosystem services, 4. Developing clear national awareness on LDN, 5. Reviewing current legislations and developing new legislations, especially those addressing the LDN concept and 6. LDN-related aspects should be implemented at land degradation hotspots and be integrated at integral regional land use planning".

8. Consequences of Land degradation on agriculture

Land degradation is an ecological phenomenon that disrupts dry regions and has an impact on the economic and natural characteristics of agricultural lands (Barbier and Hochard, 2018). Due to its negative implication on the efficiency of agricultural production, LD is fundamentally a large global concern. It also has a negative impact on food and environmental security (Abebaw, 2019). It showcases challenging behaviours towards environmental growth, distributing the negative consequences on socio-economic situations, as well as agriculture (Toor *et al.*, 2020). Land degradation is caused by natural or anthropogenic factors that might lead to a decrease in land productivity (Fig. 3). Land degradation within production implies a mismatch among good quality soil land usage (Gupta, 2019; Wassie, 2020). Approximately half agricultural land will be damaged from moderate to severe. Land degradation affects around 1.5bn people worldwide; 15bn tonnes of soil disappear annually; approximately 12M per hectare are lost annually owing to LD; and approximately 6M square kilometres of lands are converted to desert. Annually, around 27000 species are lost owing to land degradation, roughly 110 countries are possibly at risk due to deserts, impacted approximately 250M people and nearly 1bn threatened (Hamdy and Aly). (Ejersa, 2021) discovered that land degradation leads to a loss of soil organic matter and fertility, resulting in a decrease in agricultural yield. Physical LD within the root zone, according to (Mishra *et al.*, 2023) and (Saguye, 2017), is the greatest contributor to productivity loss. The primary causes of increased erosion include urban development, industrialization, deforestation, and agriculture. Tillage instruments used in agriculture destroy topsoil/plants and promote erosion (Angelsen, 2007).

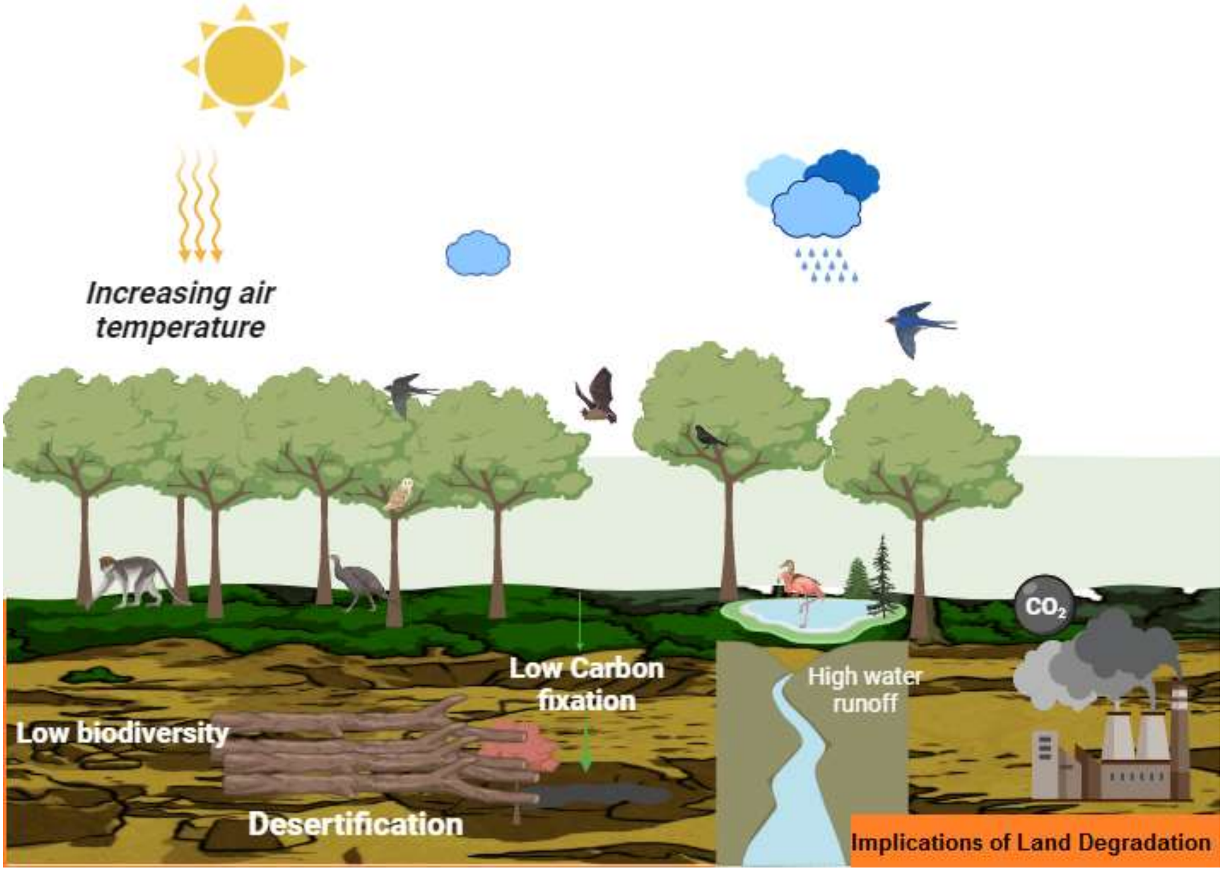

Fig. 4. Implications of land degradation.

9. Consequences of Land degradation on the environment

Land degradation has an effect on climate, production, the environment, agriculture, and biodiversity (Touré *et al.*, 2020). It also has an impact on environmental biophysics by causing damage to the land through anthropogenic and/or natural sources. Natural sources include tremors, water overflow, tidal wave and flood. Additionally, the majority of anthropogenic activities have a considerable impact on the environment (Yin *et al.*, 2019; Mosa *et al.*, 2021; Mosa *et al.*, 2022b; Wang *et al.*, 2023b). Global estimates of LD revealed that it severely affects Asia, but the impact on Europe and Africa are little (Zika and Erb, 2009). Research conducted earlier indicated that continuous volcanic activity causes land deterioration and has impacted the environment significantly (Leroy *et al.*, 2010).

9.1 Impact on greenhouse gases (GHGs)

In terms of global CO_2 land-atmosphere exchange, cultivation and agricultural management of cultivated land are important. Agricultural management practises can increase or decrease carbon losses to the atmosphere, in addition to the initial pulse of CO_2 discharges related with the start of cultivation and vegetation removal. Although worldwide croplands are thought to be near neutral in the current decade (Houghton et al., 2012), this is due to uncertain equilibrium of coexisting remaining losses and development. Soil and biomass carbon losses seems to be replaced by gains through soil renewal and preservation practises such as cover crops, conservation tillage, and nutrient replenishment that favours the build-up of organic matter.

Cover crops which are increasingly utilised to enhance soils, have the ability to sequester 0.12 GtC annually on worldwide croplands during a 150-year period (Poeplau and Don 2015). The implementation of zero-till practises protects soils from erosion and reduce land preparation times, also serve as a carbon sequestration option, which is now considered best globally (Cheesman et al., 2016; Powlson et al., 2014). Lime application for acidity correction becomes increasingly essential in tropical locations which provides a considerable amount of CO_2 source in some soils (Desalegn et al., 2017).

10. Land Degradation Management

The main approach to upgrade quality of soil is good management of irrigation water (Amer *et al.*, 2020; Feng *et al.*, 2022). Depending on the nature, extent, and form of land degradation, numerous strategies can be used to restore it. The majority of land degradation types can be recovered by adding organic matter (animal and plant remains), upgrading topsoil through soil amendments, regenerating vegetation using cover crop and green manure (Hurni *et al.*, 2015). The application of integrated soil fertility management is a comprehensive set of management approaches used to regulate and decrease the impact of land degradation to a bare minimum (Vanlauwe *et al.*, 2010; Nigussie *et al.*, 2017; Adem *et al.*, 2023). It can also be used to upgrade degraded land, increase nutrient intake, soil fertility, and organic matter dissolution, all of which contribute to increased biodiversity and soil microorganism activity (Vanlauwe *et al.*, 2010; Barrow, 2012; Adem *et al.*, 2023). In addition to conventional agricultural practise, integrated soil fertility management can be applied to rehabilitate degraded land (Henry *et al.*, 2018). Management measures that include establishment of forest plantation, organic fertiliser application, devoid crop residue clearance, crop rotation practises, bush fallow/shifting cultivation, and control overgrazing can improve soil nutrients as well as crop productive capacity (Alemu, 2015). Furthermore, to improve soil health and sustain agricultural output, immediate need to transit from native approaches to sophisticated 3Es (environmental, efficient and economically acceptable) technologies for land recovery management to achieve sustainable land management (Mishra *et al.*, 2023).

10.1 . Sustainable forest management (SFM) and CO_2 removal (CDR) techniques

Reducing deforestation and degradation of forest can directly contribute in meeting the mitigation goals. The purpose of SFM is to provide fibre, biomass, non-timber and timber resources to communities for a long term, eliminate the dangers of converting forest to non-forest and sustain productivity of the land, thereby decreasing the dangers of land degradation
(Rossi et al. 2017; Nitcheu Tchiadje et al. 2016; Sufo Kankeu et al. 2016).

Evolving SFM approaches to contribute to negative emissions over the next century necessitates knowing forest management impacts on ecosystem carbon stocks (as well as soils), carbon fluxes, carbon sinks in cut down wood, stored carbon in cut down wood products, as well as landfills and achieving reduction in emission by utilizing bioenergy and wood product (Nabuurs et al. 2007; Lemprière et al. 2013; Kurz et al. 2016; Law et al. 2018).

The net ecosystem productivity, growth rate of the forest and net basic production all depends on the age of the forest, with young to medium-aged forests having the highest rates of CO_2 removal (CDR) from the atmosphere and diminishing subsequently (Tang et al. 2014). Estimates of carbon stocks and carbon fluxes in boreal forest ecosystems showed that old growth stands are often less carbon sinks or carbon sources (Gao et al. 2018; Taylor et al. 2014; Hadden and Grelle 2016). Carbon uptake rates in tropical forests were 11 times higher in the first two decades of forest regeneration than in old-growth forests (Poorter et al. 2016).

Because of age-dependent rises in forest carbon stocks and declines in forest carbon sinks, landscapes with older forests have more accumulation of carbon but with diminishing sink strength, whereas landscapes with younger forests have less accumulation of carbon but are removing CO_2 from the atmosphere at a much faster rate (Volkova et al. 2017; Poorter et al. 2016). CDR rates are influenced not just by age, but also by a variety of physicochemical elements and anthropogenic activities (Bernal et al. 2018). The linkages between carbon stocks and sinks are essentially tedious and expensive to quantify in ecosystems with multispecies and different aged forests.

10.2 . Policy responses to land degradation

The 1992 United Nations Conference on Environment and Development (UNCED), also known as the Rio de Janeiro Earth Summit, identified land degradation as a foremost challenge to sustainable development and resulted in the creation of the UN Convention to Combat Desertification (UNCCD) that addresses land degradation in the drylands and UNCCD encourages sustainable utilization of land in order to integrate environmental protection with reduction of poverty. The land has been identified as a concern among the three conventions, and sustainable land management is planned as a uniting factor for present universal efforts to combat climate change, biodiversity loss and land degradation as well as to facilitate adaptation of land based sustainable development and climate change.

The UNCCD introduced LDN at Rio +20 and adopted it at UNCCD COP12 (UNCCD 2016a). LDN is described as "a state in which the amount and quality of land resources required to support ecosystem functions and services and improve food security remain stable or increase within specified temporal and spatial scales and ecosystems" (Cowie et al. 2018). Pursuit of LDN necessitates effort to minimise additional net loss of land-based natural capital relative to a reference baseline. LDN advocates a dual divided effort involving sustainable land management to lower the risk of land degradation, paired with initiatives in land recovery and reintegration, to sustain the natural land-based capital and related ecosystem services (Orr et al. 2017; Cowie et al. 2018).

LDN planning entails estimating the expected cumulative impacts of land use and land management decisions, next compensating for expected losses with actions to generate equal gains within specific types of land. Three major pointers are applied to know if LDN is reached by 2030 under the UNCCD LDN framework: soil organic carbon (SOC); land cover change and net primary productivity (Cowie et al. 2018; Sims et al. 2019). To achieve LDN, integrated landscape management is required, which tries to optimise land use to meet various objectives (food security, human well-being and health condition of the ecosystem) (Cohen-Shacham et al. 2016). Avoid > Reduce > Reverse land degradation is a response hierarchy that articulates the priorities in developing LDN solutions. Land degradation neutrality offers motivation for wider acceptance of sustainable land management and attempts to recover land. Through its focus, LDN eventually provides significant promise for mitigating climate change and adaptation by halting and reversing environmental degradation and changing land from a carbon source to a sink.

10.3 . Geographical Information System (GIS) and remote sensing deployment in Land degradation

Since soil is considered as the greatest carbon sink on earth, implementing agriculture that will cope with and manage the impacts of climate change is essential. Furthermore, based on the types of exposure and contacts individuals have with soil, soils can either benefit or damage human well-being (Brevik *et al.*, 2020). Depending on the field soil study, certain basic facts may be gathered, such as level of development, forms of spatiotemporal evolution and reasons of land degradation, that are important for the associated investigations. Though, there are considerable restrictions in real-world implementations due to sluggishness, cost and irregular nature of traditional field study. Moreover, certain experiments are hampered by vehicular inaccessibility and relief of the area (Lobell, 2010).

As a result, frequent collections of soil data in large-scale are unfriendly and time-consuming. Moreover, the gathered soil data are nonetheless scanty and inadequate around us (Goldshleger *et al.*, 2010). Presently, with the advancement of land degradation associated researches, high-resolution, reliable, and current soil data is increasingly becoming important (Shoshany *et al.*, 2013). Evaluating soil quality effectively is significantly difficult for pedologists in general (particularly for soil degradation). Proliferation of technologies for planet observation has gained ground since the sixties, providing extraordinary data and methodologies for discovering important details for diverse land utilizations (Liang and Wang, 2019).

Food and Agriculture Organization (FAO) data shows that, >30 percent global land resources have been degraded (UN Environment Programme (Latham *et al.*, 2014). Soil deterioration in arid and semi-arid zones is more serious worldwide. To essentially prevent these situations from worsening, significant efforts to research the process of soil deterioration and restore soil function. In essence, the integration of physical, chemical, and biological features drives the creation of soil processes and the restoration of its functions (Pereira *et al.*, 2017).

Remote Sensing (RS) technology, meets these needs by identifying and detailing the temporal features of land degradation, forecasting the spread of deteriorated lands/soil quality spatial unpredictability, and sensing natural/changes due to human-activities at individual globally levels. Remote sensing under the umbrella of planet observation development, gives an alternate view for evaluating soil deterioration (White, 2005). It can be a viable substitute to field study, especially on a significant quantity. Remotely sensed satellite imagery with high-spatiotemporal and spectral-resolution are now available, due to recent changes in tomography and planet monitoring/observation (Zhou *et al.*, 2020). RS related with the traditional field soil study, the aforementioned outperforms the latter in several ways, including: field wide view, efficiency, inexpensive, instantaneous data capturing, and sporadic imagery (Liang and Wang, 2019; Wang *et al.*, 2019). Knowing the spatiotemporal benefits of imageries remotely sensed over the few decades, the technology has increasingly shown a vital performance in the investigation of land degradation (Bai *et al.*, 2008; Sepuru and Dube, 2018; Dragović and Vulević, 2020).

Topical is the breakthroughs in algorithm achievement, as well as the expansion of cloud-based computing and large storage size, have substantially expanded the application potential of remote sensing for land degradation investigations (Fu *et al.*, 2021). By means of all of these advancements, investigations on the issue of land deterioration impacts and monitoring have tremendously increased (Sepuru and Dube, 2018; Zweifel *et al.*, 2019; Akinyemi *et al.*, 2021). Consequently, literature showed intensive publications/reports on land degradation studies employing RS data currently (Shoshany *et al.*, 2013; Ferreira *et al.*, 2022).

GIS and remote sensing technologies are a strong and profitable mechanism for evaluating spatial distribution, land cover dynamics and investigate land degradation due to its efficiency, wide-scope and time saving. Currently, it is used to study different sources of land degradation (Dewan and Yamaguchi, 2009; Wang *et al.*, 2023a). According to (El Baroudy and Moghanm, 2014), they used GIS and remote sensing to assess the risk of land degradation in some soils north of Nile Delta. Authors discovered that salinity, sodicity and waterlogging are the most common degradation risks. (Abuzaid, 2018) also used the technology to assess soil degradation on flood plains at the north east Nile delta. He discovered that slightly affected soils by degradation hazard represented about 47.8% of the total area, whereas 26.1% of the area were moderately affected and the rest of the area were strongly affected.

Conclusion

The consequences of Land degradation on livelihood, farming and the environment are enormous. This menace could be initiated by natural and/or anthropogenic factors such as climatic changes, water logging, erosion, salinization, deforestation, overgrazing, desertification, soil compaction and depletion of organic matter. Eventually, leads to decline in the quality of the soil physical, chemical and biological properties. Therefore, it is pertinent to decrease the quantity of losses due to degradation and that can be addressed through afforestation, vegetation cover, land reclamation, avoidance of total crop residues removal and integrated application of organic and inorganic fertiliser to the land. In this review valuable information at local level (Egypt) and at sub-Saharan Africa has been presented evaluating the status, types and distribution of land degradation in Egypt and in sub-Saharan Africa. The process of land degradation is complicated and differs from one location to another. Hence, the surveillance of the processes of degradation through application of GIS and remote sensing tools is regarded effective to understand the spatial-temporal features of land degradation for food security and sustainable land management

Conflicts of interest

There are no conflicts to declare

Author contribution

Conceptualisation, AMB; writing-original draft preparation, AMB; writing-critical review and editing, AAM; funding acquisition, TETfund. All authors have read and agreed to the published version of the manuscript.

Funding

The authors would like to thank Tertiary Education Trust fund of Nigeria for funding through Ibrahim Badamasi Babangida University, Lapai, Nigeria.

References

Abdel-Satar AM, Ali MH, Goher ME (2017). Indices of water quality and metal pollution of Nile River, Egypt. The Egyptian Journal of Aquatic Research 43, 21-29.

Abdelhafez AA, Metwalley SM, Abbas HH (2020). Irrigation: Water resources, types and common problems in Egypt. Technological and Modern Irrigation Environment in Egypt: Best Management Practices & Evaluation, 15-34.

Abdelhaleem FS., Basiouny M, Ashour E, Mahmoud A (2021). Application of remote sensing and geographic information systems in irrigation water management under water scarcity conditions in Fayoum, Egypt. Journal of Environmental Management 299, 113683.

Abdel Kawy WAM, Ali RR (2012). Assessment of soil degradation and resilience at northeast Nile Delta, Egypt: The impact on soil productivity. The Egyptian Journal of Remote Sensing and Space Science 15, 19-30.

Abdelhameed A, Hussien H, Abdelmontaleb AAB, Marzouk ER, Abdo MR (2020). Detection of land use/cover change in Ber El-Abd area, North Sinai, Egypt using remote sensing. Sinai Journal of Applied Sciences 9, 183-190.

AbdelMaksoud KM, Al-Metwaly WM, Ruban DA, Yashalova NN (2018). Geological heritage under strong urbanization pressure: El-Mokattam and Abu Roash as examples from Cairo, Egypt. Journal of African Earth Sciences 141, 86-93.

AbdelRahman MAE (2023). An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. Rendiconti Lincei. Scienze Fisiche eNaturali, 1-42.

AbdelRahman MAE, Arafat SM (2020). An approach of agricultural courses for soil conservation based on crop soil suitability using geomatics. Earth Systems and Environment 4, 273-285.

AbdelRahman MAE, Metwaly MM, Afifi AA, D'Antonio P, Scopa A (2022). Assessment of soil fertility status under soil degradation rate using geomatics in West Nile Delta. Land 11, 1256.

Abebaw WA (2019). Review on impacts of land degradation on agricultural production in Ethiopia. J. Resour. Dev. Manag 57.

Abu-Hashim M, Sayed A, Zelenakova M, Vranayová Z, Khalil M (2021). Soil water erosion vulnerability and suitability under different irrigation systems using parametric approach and GIS, Ismailia, Egypt. Sustainability 13, 1057.

Abuzaid A.S (2018). Assessing degradation of floodplain soils in north east Nile Delta, Egypt. Egyptian Journal of Soil Science 58, 135-146.

Adem M, Azadi H, Spalevic V, Pietrzykowski M, Scheffran J (2023). Impact of integrated soil fertility management practices on maize yield in Ethiopia. Soil and Tillage Research 227, 105595.

Akinyemi FO, Ghazaryan G, Dubovyk O (2021). Assessing UN indicators of land degradation neutrality and proportion of degraded land for Botswana using remote sensing based national level metrics. Land degradation & development 32, 158-172.

Aleminew A, Alemayehu M (2020). Soil fertility depletion and its management options under crop production perspectives in Ethiopia: A review. Agricultural Reviews 41, 91-105.

Alemu B (2015). The effect of land use land cover change on land degradation in the highlands of Ethiopia. Journal of Environment and Earth Science 5, 1-13.

Alshaal T, El-Ramady H, Al-Saeedi AH, Shalaby T, Elsakhawy T, Omara AED, Gad A, Hamad E, El-Ghamry A, Mosa A (2017). The rhizosphere and plant nutrition under climate change. Essential plant nutrients: uptake, use efficiency, and management, 275-308.

Ali RR, Abdel Kawy WAM (2013). Land degradation risk assessment of El Fayoum depression, Egypt. Arabian Journal of Geosciences 6, 2767-2776.

Amer MM, Gazia EAW, Aboelsoud HM, Rashed SH, (2020). Management of Irrigation Water and Organic Matter Application Contribution in Improving Some Soil Properties and Yields–Water Productivity of Sugar Beet and Cotton in Salt Affected Soil. Env. Biodiv. Soil Security 4, 18.

Amodio M, Catino S, Dambruoso PR, de Gennaro G, Di Gilio A, Giungato P, Laiola E, Marzocca A, Mazzone A, Sardaro A, (2014). Atmospheric deposition: sampling procedures, analytical methods, and main recent findings from the scientific literature. Advances in Meteorology 2014.

Angelsen A, (2007). Forest cover change in space and time: combining the von Thünen and forest transition theories. World Bank Publications.

Bai ZG, Dent DL, Olsson L, Schaepman ME, (2008). Global assessment of land degradation and improvement: 1. identification by remote sensing. In. ISRIC-World Soil Information.

Barbier EB, Hochard JP, (2018). Land degradation and poverty. Nature Sustainability 1, 623-631.

Barrow CJ, (2012). Biochar: potential for countering land degradation and for improving agriculture. Applied Geography 34, 21-28.

Beillouin D, Demenois J, Cardinael R, Berre D, Corbeels M, Fallot A, Boyer A, Feder F (2022). A global database of land management, land-use change and climate change effects on soil organic carbon. Scientific Data 9, 228.

Bernal B, Murray LT, Pearson TRH (2018) Global carbon dioxide removal rates from forest landscape restoration activities. Carbon balance and management 13(1):1-13

Borysova O, Kondakov A, Paleari S, Rautalahti-Miettinen E, Stolberg F, Daler D (2005). Eutrophication in the Black Sea region: impact assessment and causal chain analysis. University of Kalmar, Kalmar, Sweden

Borrelli P, Robinson DA, Panagos P, Lugato E, Yang JE, Alewell C, Wuepper D, Montanarella L, Ballabio C (2020). Land use and climate change impacts on global soil erosion by water (2015-2070). Proceedings of the National Academy of Sciences 117, 21994-22001.

Brevik EC, Slaughter L, Singh BR, Steffan JJ, Collier D, Barnhart P, Pereira P (2020). Soil and human health: current status and future needs. Air, Soil and Water Research 13, 1178622120934441.

Cheesman S, Thierfelder C, Eash NS, Kassie GT, Frossard E (2016) Soil carbon stocks in conservation agriculture systems of Southern Africa. Soil and Tillage Research 156:99-109.

Cohen-Shacham E, Walters G, Janzen C, Maginnis S (2016) Nature-based solutions to address global societal challenges. IUCN: Gland, Switzerland 97:2016-2036

Cowie AL, Orr BJ, Sanchez VMC, et al. (2018) Land in balance: The scientific conceptual framework for Land Degradation Neutrality. Environmental Science & Policy 79:25-35

Delgado JA, Gantzer CJ, (2015). The 4Rs for cover crops and other advances in cover crop management for environmental quality. Journal of Soil and Water Conservation 70, 142A-145A.

DEFRA (2002). The government's strategic review of diffuse water pollution from agriculture in England: agriculture and water: a diffuse pollution review, Department for Environment, Food and Rural Affairs, London

Desalegn T, Alemu G, Adella A, Debele T (2017) Effect of lime and phosphorus fertilizer on acid soils and barley (Hordeum vulgare L.) performance in the central highlands of Ethiopia. Experimental Agriculture 53(3):432-444

Dewan AM, Yamaguchi Y, (2009). Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005. Environmental monitoring and assessment 150, 237-249.

Dragović N, Vulević T (2020). Soil degradation processes, causes, and assessment approaches. In, Life on Land. Springer, pp. 928-939.

Ejersa MT (2021). Causes of land degradation and its impacts on agricultural productivity: A review. International Journal of Research and Innovations in Earth Science 8, 67-73.

El-Ghamry A, El-Naggar ES, Elgorban AM, Gao B, Ahmad Z, Mosa A (2021). Double Coating as a Novel Technology for Controlling Urea Dissolution in Soil: A Step toward Improving the Sustainability of Nitrogen Fertilization Approaches. Sustainability 13, 10707.

El-Ghamry A, Mosa A, El-Naggar E (2009). Optimum time for phosphorus fertilization on Egyptian alluvial soil. Acta Agronomica Hungarica 57, 363-370.

El-Naggar A, Mosa A, Ahmed N, Niazi NK, Yousaf B, Sarkar B, Rinklebe J, Cai Y, Chang SX (2022a). Modified and pristine biochars for remediation of chromium contamination in soil and aquatic systems. Chemosphere 303, 134942.

El-Naggar A, Mosa A, Amin AEE, Yang X, Yousaf B, El-Naggar AH, Cai Y, Chang SX (2022b). Biochar for remediation of alkaline soils contaminated with toxic elements. In, Biochar in Agriculture for Achieving Sustainable Development Goals. Elsevier, pp. 223-240.

El-Ramady H, Alshaal T, Bakr N, Elbana T, Mohamed E, Belal AA (2018). The soils of Egypt. Springer.

El-Rawy M, Abdelrahman MA, Ismail E (2020). INTEGRATED USE OF POLLUTION INDICES AND GEOMATICS TO ASSESS SOIL CONTAMINATION AND IDENTIFY SOIL POLLUTION SOURCE IN EL-MINIA GOVERNORATE, UPPER EGYPT. Journal of Engineering Science and Technology 15, 2223-2238.

El Baroudy AA, Moghanm FS, (2014). Combined use of remote sensing and GIS for degradation risk assessment in some soils of the Northern Nile Delta, Egypt. The Egyptian Journal of Remote Sensing and Space Science 17, 77-85.

Elnaggar A, El-Hamidi K, Mousa M, Albakry M (2017). Mapping soil salinity and evaluation of water quality in Siwa Oasis using GIS. Journal of Soil Sciences and Agricultural Engineering 8, 9-19.

Elnaggar A (2020). Evaluation of land degradation in agricultural areas within damietta governorate, Egypt Caused by Urban Encroachment, Salinity, Sodicity and Loss of Fertility. Journal of Soil Sciences and Agricultural Engineering 11, 741-749.

Elnaggar A, Mosa A, El-Seedy M, Biki F (2016a). Evaluation of Soil Agricultural Productive Capability by Using Remote Sensing and GIS Techniques in Siwa Oasis, Egypt. Journal of Soil Sciences and Agricultural Engineering 7, 547-555.

Elnaggar, A., Mosa, A., Shebiny, G., El-Seedy, M., El-Bakry F (2016b). Evaluation of Soil Fertility by Using GIS Techniques for Some Soils of Dakahlia Governorate, Egypt. Journal of Soil Sciences and Agricultural Engineering 7, 713-720.

Elnaggar A (2020). Evaluation of land degradation in agricultural areas within damietta governorate, Egypt Caused by Urban Encroachment, Salinity, Sodicity and Loss of Fertility. Journal of Soil Sciences and Agricultural Engineering 11, 741-749.

Elnaggar AA, Azeez AA, Mowafy M (2020). Monitoring Spatial and Temporal Changes of Urban Growth in Dakahlia Governorate, Egypt, by Using Remote Sensing and GIS Techniques. MEJ. Mansoura Engineering Journal 39, 1-14.

Enar KA, El Baroudy AA, Shokr MS (2021). Assessment and mapping land degradation in some areas of North Nile Delta, using new techniques. Menoufia Journal of Soil Science 6, 265-274.

Feng S, Zhao W, Zhan T, Yan Y, Pereira P (2022). Land degradation neutrality: A review of progress and perspectives. Ecological Indicators 144, 109530.

Fenta AA, Tsunekawa A, Haregeweyn N, Poesen J, Tsubo M, Borrelli P, Panagos P, Vanmaercke M, Broeckx J, Yasuda H (2020). Land susceptibility to water and wind erosion risks in the East Africa region. Science of the Total Environment 703, 135016.

Ferreira CSS, Seifollahi-Aghmiuni S, Destouni G, Ghajarnia N, Kalantari Z (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. Science of the Total Environment 805, 150106.

Fu DJ, Xiao H, Su FZ, Zhou CH, Dong JW, Zeng YL, Yan K, Li SW, Wu J, Wu WZ (2021). Remote sensing cloud computing platform development and Earth science application. National Remote Sensing Bulletin 25, 220-230.

Gao B, Taylor AR, Searle EB, et al. (2018) Carbon storage declines in old boreal forests irrespective of succession pathway. Ecosystems 21:1168-1182

Goldshleger N, Ben-Dor E, Lugassi R, Eshel G (2010). Soil degradation monitoring by remote sensing: examples with three degradation processes. Soil Science Society of America Journal 74, 1433-1445.

Gondek M, Weindorf DC, Thiel C, Kleinheinz G (2020). Soluble salts in compost and their effects on soil and plants: A review. Compost Science & Utilization 28, 59-75.

Gupta GS (2019). Land degradation and challenges of food security. Rev. Eur. Stud. 11, 63.

Hadden D, Grelle A (2016) Changing temperature response of respiration turns boreal forest from carbon sink into carbon source. Agricultural and Forest Meteorology 223:30-38

Hamdy A, Aly A, Land degradation, agriculture productivity and food security. In, pp. 708-717.

Hamed MM, Nashwan MS, Shahid S (2022). Climatic zonation of Egypt based on high-resolution dataset using image clustering technique. Progress in Earth and Planetary Science 9, 1-16.

Haregeweyn N, Tsunekawa A, Tsubo M, Fenta AA, Ebabu K, Vanmaercke M, Borrelli P, Panagos P, Berihun ML, Langendoen EJ (2023). Progress and challenges in sustainable land management initiatives: A global review. Science of The Total Environment 858, 160027.

Hassan HHM, El-sobky ESEA, Mansour E, El-Kholy ASM, Ullah H, Datta A (2022). Influence of preceding crop and tillage system on forage yield and quality of selected summer grass and legume forage crops under arid conditions. Journal of Integrative Agriculture 21, 3329-3344.

Houghton RA, House JI, Pongratz J, et al. (2012) Carbon emissions from land use and land-cover change. Biogeosciences 9(12):5125-5142.

Heffer P, Prud'homme M, (2014). Fertilizer Outlook 2014–2018. Paris, France: International Fertilizer Industry Association (IFA).

Henry B, Murphy B, Cowie A (2018). Sustainable land management for environmental benefits and food security. A synthesis report for the GEF. Washington DC, USA 127.

Hossain A, Krupnik TJ, Timsina J, Mahboob MG, Chaki AK, Farooq M, Bhatt R, Fahad S, Hasanuzzaman M (2020). Agricultural land degradation: processes and problems undermining future food security. In, Environment, climate, plant and vegetation growth. Springer, pp. 17-61.

Hurni K, Zeleke G, Kassie M, Tegegne B, Kassawmar T, Teferi E, Moges A, Tadesse D, Ahmed M, Degu Y (2015). Economics of Land Degradation (ELD) Ethiopia Case Study: Soil degradation and sustainable land management in the rainfed agricultural areas of Ethiopia: An assessment of the economic implications.

Jamil A, Riaz S, Ashraf M, Foolad MR (2011) Gene expression profiling of plants under salt stress. Critical Reviews in Plant Sciences 30, 435–458.

Janmaat J (2005). Water applications and Pigouvian taxes to control irrigation-induced soil degradation. Journal of Development Economics 76, 209-230.

Kayombo B, Lal R (1993). Tillage systems and soil compaction in Africa. Soil and Tillage Research 27, 35-72.

Kirui OK, Mirzabaev A (2014). Economics of land degradation in Eastern Africa. ZEF working paper series.

Kurz WA, Smyth C, Lemprière T (2016) Climate change mitigation through forest sector activities: principles, potential and priorities 1. Unasylva 67(246):61

Latham J, Cumani R, Rosati I, Bloise M (2014). Global land cover share (GLC-SHARE) database beta-release version 1.0-2014. FAO: Rome, Italy 29.

Law BE, Hudiburg TW, Berner LT, Kent JJ, Buotte PC, Harmon ME (2018) Land use strategies to mitigate climate change in carbon dense temperate forests. Proceedings of the National Academy of Sciences 115(14):3663-3668

Lemprière TC, Kurz WA, Hogg EH, et al. (2013) Canadian boreal forests and climate change mitigation. Environmental Reviews 21(4):293-321

Leroy SAG, Warny S, Lahijani H, Piovano EL, Fanetti D, Berger AR (2010). The role of geosciences in the mitigation of natural disasters: five case studies. Springer.

Li D, Daler D (2004). Ocean pollution from land-based sources: East China Sea, China. Ambio 33:107-113

Liang S, Wang J (2019). Advanced remote sensing: terrestrial information extraction and applications. Academic Press.

Lobell DB (2010). Remote sensing of soil degradation: introduction. Journal of Environmental Quality 39, 1-4.

Marczak D, Lejcuś K, Kulczycki G, Misiewicz J (2022). Towards circular economy: Sustainable soil additives from natural waste fibres to improve water retention and soil fertility. Science of the Total Environment 844, 157169.

Misak RF, Draz M.Y (1997). Sand drift control of selected coastal and desert dunes in Egypt: case studies. Journal of Arid Environments 35, 17-28.

Mishra AK, Das R, George Kerry R, Biswal B, Sinha T, Sharma S, Arora P, Kumar M (2023). Promising management strategies to improve crop sustainability and to amend soil salinity. Frontiers in Environmental Science 10, 962581.

Moghanm FS, El-Banna A, El-Esawi MA, Abdel-Daim MM, Mosa A, Abdelaal KAA (2020). Genotoxic and anatomical deteriorations associated with potentially toxic elements accumulation in water hyacinth grown in drainage water resources. Sustainability 12, 2147.

Mohamed ES, Abu-hashim M, AbdelRahman MAE, Schütt B, Lasaponara R (2019). Evaluating the effects of human activity over the last decades on the soil organic carbon pool using satellite imagery and GIS techniques in the Nile Delta Area, Egypt. Sustainability 11, 2644.

Mohamed NN (2017). Management of salt-affected soils in the Nile Delta. The Nile Delta, 265-295.

Mohamed E, Belal AA, Ali RR, Saleh A, Hendawy EA (2019). Land degradation. The soils of Egypt, 159-174.

Molnárová KJ, Sklenička P, Bohnet IC, Lowther-Harris F, van den Brink A, Moghaddam SM, Fanta V, Zástěra V, Azadi H (2023). Impacts of land consolidation on land degradation: A systematic review. Journal of Environmental Management 329, 117026.

Mortada WI, El-Naggar A, Mosa A, Palansooriya KN, Yousaf B, Tang R, Wang S, Cai Y, Chang SX (2023). Biogeochemical behaviour and toxicology of chromium in the soil-water-human nexus: A review. Chemosphere 331, 138804.

Mosa A, Hawamdeh OA, Rady M, Taha AA (2023a). Ecotoxicological monitoring of potentially toxic elements contamination in Eucalyptus forest plantation subjected to long-term irrigation with recycled wastewater. Environmental Pollution 329, 121739.

Mosa A, Mansour MM, Soliman E, El-Ghamry A, El Alfy M, El Kenawy AM (2023b). Biochar as a Soil Amendment for Restraining Greenhouse Gases Emission and Improving Soil Carbon Sink: Current Situation and Ways Forward. Sustainability 15, 1206.

Mosa A, Selim EMM, El-Kadi SM, Khedr AA, Elnaggar AA, Hefny WA, Abdelhamid AS, El Kenawy AM, El-Naggar A, Wang H, (2022a). Ecotoxicological assessment of toxic elements contamination in mangrove ecosystem along the Red Sea coast, Egypt. Marine Pollution Bulletin 176, 113446.

Mosa A, Selim E-MM, El-Kadi SM, Khedr AA, Elnaggar AA, Hefny WA, Abdelhamid AS, El Kenawy AM, El-Naggar A, Wang H, Shaheen SM (2022b). Ecotoxicological assessment of toxic elements contamination in mangrove ecosystem along the Red Sea coast, Egypt. Marine Pollution Bulletin 176, 113446.

Mosa A, Taha AA, Elsaeid M (2021). In-situ and ex-situ remediation of potentially toxic elements by humic acid extracted from different feedstocks: Experimental observations on a contaminated soil subjected to long-term irrigation with sewage effluents. Environmental Technology & Innovation 23, 101599.

Mosa AA, Taha A, Elsaeid M (2020). Agro-environmental applications of humic substances: A critical review. Egyptian Journal of Soil Science 60, 211-229.

Nigussie Z, Tsunekawa A, Haregeweyn N, Adgo E, Nohmi M, Tsubo M, Aklog D, Meshesha DT, Abele S (2017). Factors influencing small-scale farmers’ adoption of sustainable land management technologies in north-western Ethiopia. Land use policy 67, 57-64.

Nitcheu Tchiadje S, Sonwa DJ, Nkongmeneck B-A, Cerbonney L, Sufo Kankeu R (2016) Preliminary estimation of carbon stock in a logging concession with a forest management plan in East Cameroon. Journal of Sustainable Forestry 35(5):355-368

Nkonya E, Anderson W, Kato E, Koo J, Mirzabaev A, von Braun J, Meyer S (2016). Global cost of land degradation. Economics of land degradation and improvement–A global assessment for sustainable development, 117-165.

Omran E-SE, Negm AM (2020). Egypt’s environment from satellite. Environmental remote sensing in Egypt, 23-91.

Orr BJ, Cowie AL, Castillo Sanchez VM, et al. (2017) Scientific conceptual framework for land degradation neutrality: a report of the science-policy interface.

Pereira P (20200. Ecosystem services in a changing environment. In, p. 135008.

Pereira P, Brevik EC, Muñoz-Rojas M, Miller BA, Smetanova A, Depellegrin D, Misiune I, Novara A, Cerdà A (2017). Soil mapping and processes modeling for sustainable land management. In, Soil mapping and process modeling for sustainable land use management. Elsevier, pp. 29-60.

Philip G, Attia OEA, Draz MY, El Banna MS Dynamics of sand dunes movement and their environmental impacts on the reclamation area in Nw Sinai, Egypt. In, pp. 169-180.

Poeplau C, Don A (2015) Carbon sequestration in agricultural soils via cultivation of cover crops–A meta-analysis. Agriculture, Ecosystems & Environment 200:33-41.

Poorter L, Bongers F, Aide TM, et al. (2016) Biomass resilience of Neotropical secondary forests. Nature 530(7589):211-214

Powlson DS, Stirling CM, Jat ML, et al. (2014) Limited potential of no-till agriculture for climate change mitigation. Nature climate change 4(8):678-683

Priori S, Pellegrini S, Vignozzi N, Costantini EAC (2020). Soil Physical-Hydrological Degradation in the Root-Zone of Tree Crops: Problems and Solutions. Agronomy 11, 68.

Rossi V, Claeys F, Bastin D, et al. (2017) Could REDD+ mechanisms induce logging companies to reduce forest degradation in Central Africa? Journal of Forest Economics 29:107-117

Saguye .S (2017). An Empirical Analysis of Land Degradation Risk from Local Community Knowledge Perspective: The Case of Geze Gofa District, Southern Ethiopia. Journal of Culture, Society and Development 28, 48-64.

Saleem AA, Abel-Rahman AK, Ali AHH, Ookawara S (2016). An analysis of thermal comfort and energy consumption within public primary schools in Egypt. IAFOR J. Sustain. Energy Environ 3.

Saljnikov E, Mirschel W, Prasuhn, V, Keller T, Blum WEH, Chumbaev AS, Zhang J, Abuduwaili J, Eulenstein F, Lavrishchev A (2022). Types of physical soil degradation and implications for their prevention and monitoring. Advances in Understanding Soil Degradation, 43-73.

Sayed AMR, Hiroshi Y, Goto T, Enteria N, Radwan MM, Eid MA (2014). An analysis of thermal comfort for indoor environment of the New Assiut Housing in Egypt. International Journal of Architectural and Environmental Engineering 7, 381-387.

Sayed YA, A.I El-Desoky (2019). Spatial distribution and degradation risk assessment of some cultivated alluvial soils of Al-azhar University, Assiut Governorate, Egypt. Menoufia J. Soil Sci., Vol. 4 101-111

Sepuru TK, Dube T (2018). An appraisal on the progress of remote sensing applications in soil erosion mapping and monitoring. Remote Sensing Applications: Society and Environment 9, 1-9.

Sims NC, England JR, Newnham GJ, et al. (2019) Developing good practice guidance for estimating land degradation in the context of the United Nations Sustainable Development Goals. Environmental Science & Policy 92:349-355

Shoshany M, Goldshleger N, Chudnovsky A (2013). Monitoring of agricultural soil degradation by remote-sensing methods: A review. International Journal of Remote Sensing 34, 6152-6181.

Singh JS, Pandey VC, Singh DP (2011). Efficient soil microorganisms: a new dimension for sustainable agriculture and environmental development. Agriculture, ecosystems & environment 140, 339-353.

Solomon SD (2007) Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change 2007.

Stringer LC (2008). Reviewing the International Year of Deserts and Desertification 2006: What contribution towards combating global desertification and implementing the United Nations Convention to Combat Desertification? Journal of Arid Environments 72, 2065-2074.

Sufo Kankeu R, Sonwa DJ, Eba’a Atyi R, Moankang Nkal NM (2016) Quantifying post logging biomass loss using satellite images and ground measurements in Southeast Cameroon. Journal of forestry research 27:1415-1426

Tang J, Luyssaert S, Richardson AD, Kutsch W, Janssens IA (2014) Steeper declines in forest photosynthesis than respiration explain age-driven decreases in forest growth. Proceedings of the National Academy of Sciences 111(24):8856-8860

Taylor AR, Seedre M, Brassard BW, Chen HYH (2014) Decline in net ecosystem productivity following canopy transition to late-succession forests. Ecosystems 17:778-791

Thomas RJ, Quillérou E, Stewart N (2013). The rewards of investing in sustainable land management.

Tiemann T, Douxchamps S (2023). Opportunities and challenges for integrated smallholder farming systems to improve soil nutrient management in Southeast Asia. World Development Sustainability, 100080.

Toor MD, Adnan M, Raza A, Ahmed R, Arshad A, Maqsood H, Abbas F, Shehzad MH, Zafar MK (2020). Land degradation and its management: a review. International Journal of Environmental Sciences & Natural Resources 25, 63-66.

Touré I, Larjavaara M, Savadogo P, Bayala J, Yirdaw E, Diakite A (2020). Land degradation along a climatic gradient in Mali: Farmers' perceptions of causes and impacts. Land Degradation & Development 31, 2804-2818.

Turner KG, Anderson S, Gonzales-Chang M, Costanza R, Courville S, Dalgaard T, Dominati E, Kubiszewski I, Ogilvy S, Porfirio L (2016). A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. Ecological Modelling 319, 190-207.

Unccd (2005). UN convention to combat desertification–Egyptian national action program to combat desertification. In. Desert Research Center Cairo.

Unccd (2016) Report of the Conference of the Parties on its twelfth session, held in Ankara from 12 to 23 October 2015. Part two: Actions. ICCD/COP (12)/20/Add. 1. United Nations Convention to Combat Desertification (UNCCD), Bonn.

Unit JI (2005). Review of the management, administration and activities of the secretariat of the United Nations Convention to Combat Desertification (UNCCD).

Vanlauwe B, Bationo A, Chianu J, Giller KE, Merckx R, Mokwunye U, Ohiokpehai O, Pypers P, Tabo R, Shepherd KD (2010). Integrated soil fertility management: operational definition and consequences for implementation and dissemination. Outlook on agriculture 39, 17-24.

Volkova L, Bi H, Hilton J, Weston CJ (2017) Impact of mechanical thinning on forest carbon, fuel hazard and simulated fire behaviour in Eucalyptus delegatensis forest of south-eastern Australia. Forest Ecology and Management 405:92-100

Wang J, Ding J, Yu D, Ma X, Zhang Z, Ge X, Teng D, Li X, Liang J, Lizaga I (2019). Capability of Sentinel-2 MSI data for monitoring and mapping of soil salinity in dry and wet seasons in the Ebinur Lake region, Xinjiang, China. Geoderma 353, 172-187.

Wang J, Zhen J, Hu W, Chen S, Lizaga I, Zeraatpisheh M, Yang X (2023a). Remote sensing of soil degradation: Progress and perspective. International Soil and Water Conservation Research.

Wang Q, Huo Z, Zhang L, Wang J, Zhao Y (2016). Impact of saline water irrigation on water use efficiency and soil salt accumulation for spring maize in arid regions of China. Agricultural Water Management 163, 125-138.

Wang X (2022). Managing land carrying capacity: Key to achieving sustainable production systems for food security. Land 11, 484.

Wang Z, Ma J, Wang T, Qin C, Hu X, Mosa A, Ling W (2023b). Environmental health risks induced by interaction between phthalic acid esters (PAEs) and biological macromolecules: A review. Chemosphere 328, 138578.

Wassie SB (2020). Natural resource degradation tendencies in Ethiopia: a review. Environmental systems research 9, 1-29.

Wassif MM (2002). Determination of wind erosion precipitation and the economic measures to combat desertification in Western Desert Oases. ARE in participation with University of QarYunis-Benghazi-Libya.

White RE (2005). Principles and practice of soil science: the soil as a natural resource. John Wiley & Sons.

Xu D, Sun H, Wang J, Wang N, Zuo Y, Mosa AA, Yin X (2023). Global trends and current advances regarding greenhouse gases in constructed wetlands: A bibliometric-based quantitative review over the last 40 years. Ecological Engineering 193, 107018.

Yang J-l, Ren L-q, Zhang N-h, Liu E-k, Sun S-k, Ren X-l, Jia Z-k, Wei T, Zhang P (2023). Can soil organic carbon sequestration and carbon management index be improved by changing the film-mulching methods in semiarid region? Journal of Integrative Agriculture.

Yin X, Yu L, Luo X, Zhang Z, Sun H, Mosa AA, Wang N (2019). Sorption of Pb (II) onto <1 μm effective diameter clay minerals extracted from different soils of the Loess Plateau, China. Geoderma 337, 1058-1066.

Zhou T, Geng Y, Chen J, Pan J, Haase D, Lausch A, (2020). High-resolution digital mapping of soil organic carbon and soil total nitrogen using DEM derivatives, Sentinel-1 and Sentinel-2 data based on machine learning algorithms. Science of The Total Environment 729, 138244.

Zika M, Erb K-H (2009). The global loss of net primary production resulting from human-induced soil degradation in drylands. Ecological economics 69, 310-318.

Zweifel L, Meusburger K, Alewell C (2019). Spatio-temporal pattern of soil degradation in a Swiss Alpine grassland catchment. Remote sensing of environment 235, 111441.