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Desertification seen through the eyes of a group of international students

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ABSTRACT

Desertification is one of the most serious environmental problems worldwide, with its impacts manifesting locally meaning that causes, natural as well as human-induced, vary not only country-wise but also within the country depending on the physiography (climate, geology, geomorphology, and soils) and the socio-cultural-political structure. The inherent ecological fragility of resources, the adverse climatic conditions, and the severe recurrent drought deserve more attention with the upcoming problem of global warming. Let's not forget that we (the human being) are not only the 'victim' but also the 'main agent' of land degradation, with the simple reason that even when the natural factors would not be favourable, this is we (human being) who is the manager. The purpose of this paper is multiple, namely, to keep up with remembering the vitality of desertification; to hear how the people in the vulnerable countries (participants of the workshop, in our case) experience and cope with it; to conceptualize the situation in different countries (of the participants); and to make eventually an attempt to digitize its assessment in Geographic Information System (GIS) environment. Many specialists, worldwide, have been researching degradation and desertification and published the results as journal articles and in books and/or reports that have been sent to the responsible departments in the country but whether their works have ever reached the decision makers in the government, and to what extent are they executed? We tried in a three-week workshop to hear the viewpoints (by means of writing essay) of a group of international university students (all holders of Bachelor and higher degrees) on this issue.

1. Introduction

Although the product of the desertification process, i.e., the 'desert' is known to everyone, one might doubt whether the process itself is known as well, when referring to its different definitions. This is to a certain extent understandable considering the complexity of the process, and the fact that the process is not initiated by only one but by many sectors, directly or indirectly, and at different levels. The three most referenced definitions of desertification by UNDP, UNCCD, UNEP, among many others, all imply the complexity of the process. However, the underlying core points may be summarized in a short phrase, namely 'a reduction in the productivity of the land that is not reversible'. Desertification reduces the potentiality of land to support life; affecting people as well as wildlife, and domestic animals due to the simple reason that the land is exhausted and can no longer support any vegetation/ plant growth.

The causative factors --natural (climate, geomorphology, soils, etc.) or human-induced (cultural, socio-political, socio-economic structure, etc.) -- vary not only country-wise, that is dependent on socio-cultural structure, but also within a country depending on the physiography (Fig. 1). Referring, as an example to the African continent [1], besides the estimated 319 million hectares of land being highly vulnerable to desertification (FAO/UNEP assessment of land degradation in Africa) there is also a considerable percentage (>30%) of the land classified as moderate to very highly vulnerable in the continent (USDA) (Table 1).

The aridification phenomena (lowering groundwater level that causes changing of the soil moisture regime), soil/ land degradation, drought, overgrazing, over-farming, deforestation, and forest fire are inseparable from the phenomenon because they can end in desertification if are not timely noticed and remedied. Decrease of the land's biological productivity caused by any agent - human-induced and/or environmental - must be considered as an alarm. No doubt that a drop in productivity for a few years should not be mistaken for a long-term loss, i.e., desertification.

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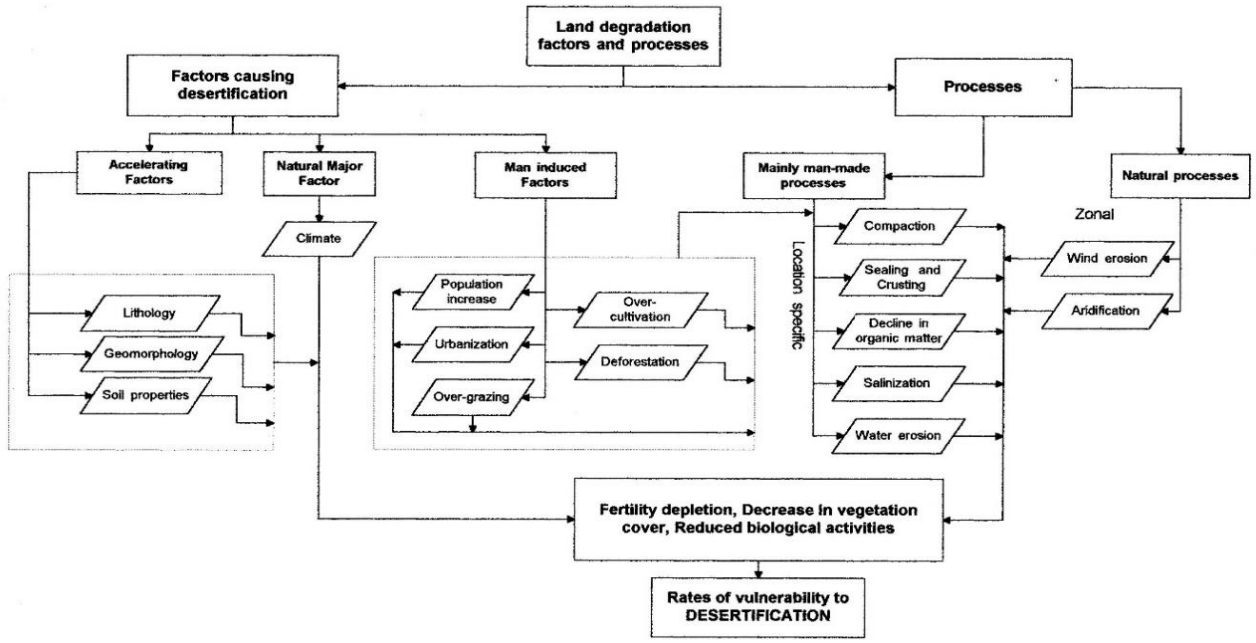


Fig. 1: An example of conceptualization, where the role of causative factors and processes are shown for an area in an African country.

Table 1(shortened): Vulnerable lands to desertification in Africa (USDA*).

Country	Area (1,000 km²) % of total	Vulnerability Low	Moderate	High	Very High
Africa	Area	4,224	4,740	3,213	1,465
	%	14.18	15.91	10.78	4.92
Egypt	Area	1	1	6	17
	%	0.13	0.15	o.66	1.74
Ethiopia	Area	265	73	131	87
	%	23.73	6.56	11.74	7.80
Kenya	Area	27	38	79	94
	%	4.83	6.75	12.34	16.69

*According to the FAO report [1] up to 65% of Africa's productive land is degraded and desertification affects 45% of the total land on the continent.

Vulnerability to desertification can be rated, though not so easy, if the causes are recognized [2,3]. The two fundamental causes are: 1) ecological conditions, and 2) human factors. The ecological conditions can be grouped into the inherent ecological fragility of resources [4], the adverse climatic conditions, and the severe recurrent drought, a phenomenon that is accelerated with the upcoming problem of global warming. The belt of deserts covering parts or whole countries of Saudi Arabia, Somali, Iran, Iraq, Burkina Faso, Ethiopia, the Gambia, Niger, Nigeria, Senegal, Fiji, and Haiti, where encroachment was a serious problem, can now be questioned as the desertification process is not limited to this belt anymore but it also occurs in many other regions outside this belt [5]. With increasing attention to the hot issue of 'climate change/ global warming' the problem of desertification is rightly more and more noticed. Earth scientists using the 'time scale', have shown the changes in climate in the geologic history. To take the history of the quaternary, in the ice age one sees cycles of glaciation with ice sheets advancing (known as glacial periods) and retreating (called interglacial periods). Currently, we are in an interglacial period (Holocene), which started about 10 to 11 thousand years ago. Geoscientists predicted the next ice age to occur 50 thousand years from now but the emissions of CO_2 and other gases into the atmosphere resulting from the intensive use of fossil fuels, and from industries, aviation, urbanization, and agriculture—greenhouse gases—will either prevent the next ice age or it can be expanded for hundreds of thousands of years [6].

The proposed measures by climate tops (ex. UN Framework Convention on Climate-- COP26 in Glasgow) should help combat desertification. After 12 days of intense negotiations, COP26 concluded on Saturday 13th November 2021-- with the representatives of almost 200 countries - approved the Glasgow Climate Pact. This global agreement is meant to accelerate the promised actions, and it completes the Paris Rulebook. The following four goals which received attention in COP26 and agreed upon are: (1) Mitigation - reducing emissions, (2) Adaptation - helping those already impacted by climate change, (3) Finance - enabling countries to deliver on their climate goals, and (4) Collaboration - working together to deliver even greater action.

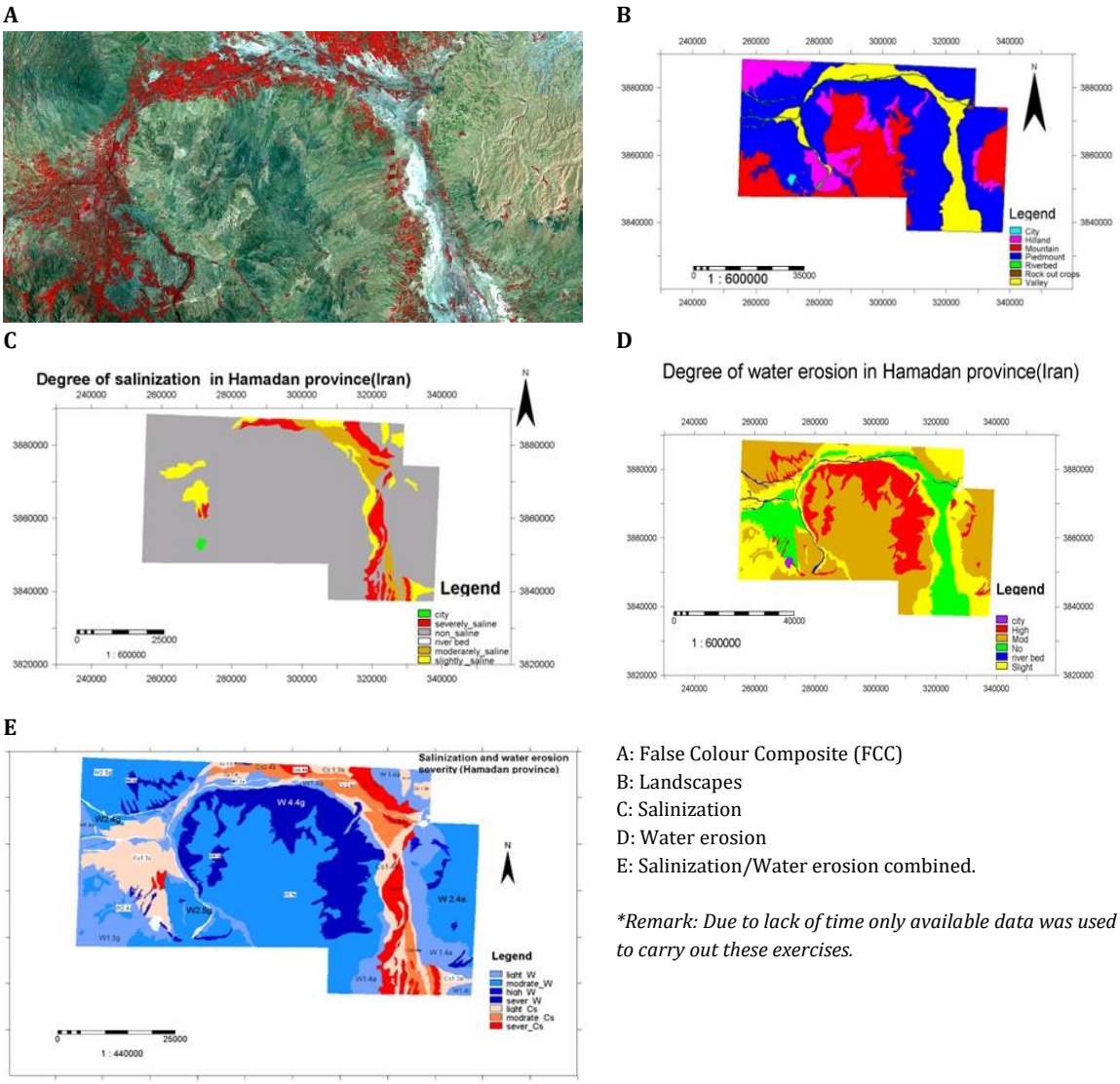
Causal factors of desertification are mainly climate-related, though initially natural but undoubtedly triggered by human actions. In drier areas, evapotranspiration exceeds far beyond annual precipitation, leading to a deficit of soil moisture that affects vegetation growth. Thus, a change in vegetation cover is an indication of desertification, which can be assessed using remote sensing data, such as freely available Landsat and Sentinel [7]. Besides, vegetation cover data at 1 km resolution (SPOT NDVI data) can be obtained cost-free. Analysis of long-term vegetation cover change and climatic data will help to understand the vegetation change pattern in an area and to see if it is related to climate change or due to other human activities [8]. To map desert-like features using hyperspectral data can indicate the start of the desertification process in an area [9]. Remote sensing data has been used in assessing physical soil degradation and in mapping soil salinization, a process of capillary rise of saline groundwater in drier areas [9,10], and in mapping soil salinization at an earlier stage using geophysical technique [11]. The objective of this paper is to demonstrate how a group of international

students perceives desertification and how the process is assessed in a scarce data environment. Also, mitigation and adaptation measures are presented.

2. Materials and Methods

2.1. Study areas

The common study areas for all participants, where everyone (in different groups) carried out topic-based exercises were the Hamadan-Komijan area in Iran (Fig. 2), and the Tabernas-Sorbas area in Almeria Province, Southern Spain.



A: False Colour Composite (FCC)
B: Landscapes
C: Salinization
D: Water erosion
E: Salinization/Water erosion combined.

**Remark: Due to lack of time only available data was used to carry out these exercises.*

Fig. 2: Assessment of two dominant types of degradation processes, using the GLASOD approach [12].

In the last part of the workshop, each participant chose an area in their own country to prepare an essay including the first phase in model development, i.e., conceptualization (ITC, 2010). Participants of the workshop coming from countries in Asia, Africa, and Southern Europe shared some similarities in terms of environment (physiography and climate) but were different when considering socio-cultural-political structure. Below, is a very short description of the study areas, including the dominant cause(s) of desertification. A valid remark is that the descriptions cover the area under study, which might be different physically from that of the country as a whole, but share a similar political structure by being parts of the country:

1. Egypt: 96% of the Egyptian land is considered 'desert'. The arid climate is the result of the country's location being close to the Sahara, its geomorphology and wind direction; a kind of barrier that prevents humid air from entering the Sahara region [13]. Water is scarce, with the main source being the Nile River, the limited amount of groundwater, and the rare rainfall mainly on the north coast. Regarding the role of human factors, among other things, overpopulation, and mismanagement can be named.
2. Ethiopia: Exhibits extensive diversity physiographically, which is mainly because of the variations in altitude. The lowland with arid, semi-arid, and dry subhumid accounts for about 46% of the total arable land. In most parts of these arid and semi-arid areas, the monthly potential evapotranspiration exceeds the amount of rainfall making them vulnerable to frequent droughts. Regarding human factors, population explosion, and overgrazing are mentioned.

3. Iran: A large country, with diverse physiography. Two study areas were chosen: The Garmsar area located in the southern part of the Alborz Mountain range, where the piedmont runs into a broad depression [14,15], and the Hamadan-Komijan area consisting of mountain, hilland, piedmont, and valley [16]. The dominant causes besides the natural ones (lithology and geomorphology) are fuelwood gathering, overgrazing, farming mismanagement, and compaction. Iran also suffers from population explosion which has led to unsustainable management of resources.
4. Kenya: Ranks as one of the most vulnerable to desertification compared to other African countries, considering the inherited ecology [17,18], population growth, and man's activities. If the current unsustainable management of resources continues a large part of the country may become a complete desert.
5. Libya: 90 to 95% of the Libyan land is considered desert. It is characterized by having a dry and hot climate, with 25 mm rainfall (except for the coastal area), dust storms, water shortage leading to overexploitation of groundwater, population exploitation, and consequently over-grazing/cultivation, and mismanagement of land.
6. Namibia: Besides the inherited ecology (low rainfall, high temperature, wind) several economic and socio-cultural issues divide the country into commercial and communal areas, each with its own problems.
7. Nigeria: Besides the harsh climatic conditions, with annual rainfall varying from 500 mm in the northeast, influenced by the dry harmattan, to 3000 mm/year on the coast, Nigeria is the most populous African country, with its all consequences; over-grazing/cultivation. Nigeria has experienced socio-political (colonialism) instability, with its expected negative consequences.
8. Spain: The most climatically diverse country in Europe, mainly known as temperate, but in the south desert-like conditions prevail. The area under the study is considered a basin in the mountain ranges, Sierra de los Filabres in the north and Sierra Alhamilla in the south respectively [19].
9. Sudan: Besides the harsh climatic conditions and the physiographic setting, which makes the country vulnerable to land degradation, population exploitation, civil war, migration, and mismanagement are named in describing the study area.
10. Tanzania: Here too physiographic and geologic settings plus climate variations are held responsible for desertification, accelerated by land degradation because of overpopulation and mismanagement.
11. Thailand: The climate of the area under study is tropical. Under the pressure of over-population deforestation in the hilly/mountainous areas is common and bare areas are washed by rain and transported easily down the slope. The physiographic (geomorphology, lithology, and soil properties) setting accelerates the process. Regarding man-induced factors urbanization, over-grazing/cultivation, and salinization are reported.
12. Uganda: The region under study is a semi-arid /sub-humid part of the country. Unfavorable physiographic setting in terms of soils which are acidic and poor with low organic carbon content, and Savana type of vegetation. These plus underlying socio-cultural-political factors form a short description of the study area.
13. Zambia: Located on the Central African plateau, with tropical wet and dry and small stretches of semi-arid steppe climate in the southwest and along the Zambezi valley. Unfavorable physiographic setting plus lack of management has led to soil degradation, soil acidity, and compaction.

2.2. Methods

Assessment of desertification status becomes possible using remote sensing (RS) and the techniques offered by the geographic information system (GIS). Basic physical data such as topography, soil, climate, and vegetation cover are required which can be extracted either from the existing databases or otherwise through fieldwork (Fig. 2). Quantifying desertification is a complex exercise, not only because many physical and human-oriented indicators must be taken into consideration but also because of the complications when interactions between factors are to be assessed. In a three-weeklong workshop, participants (international students) received lectures on soil/land degradation and desertification, backed with remote sensing (RS) and geographic information system (GIS). The participants, all with at least a B.Sc. and some with higher university degrees were attending a modular specialization course of one or two years in the application of RS and GIS in their field of interest (geology, geomorphology, vegetation, agriculture, etc). The workshop on desertification was scheduled after the introductory modules. Here, use was made of the known 'problem and objective trees analysis' tool, also used by many international agencies and consulting firms (Ex. World Bank, USDA, Norad, GTZ, etc.) in support of a project design, and a wide variety of problem structuring and problem-solving activities [20]. Further, the use was made of databases and satellite images to support their findings. Satellite images of a selected area in his/her country of different periods were used to make a false colour composite (FCC) for interpretation and calculation of NDVI (Normalized Difference Vegetation Index) purposes to detect the changes in vegetation cover over time. A few techniques applied by the participants, using the facilities offered by the ILWIS, an integrated remote sensing data analysis, and a raster-based GIS software system (Getting started with ILWIS 386 - itc.nl), are presented here. In the case of the Tabernas-Sorbas area in Spain, the "Iranian approach to assess desertification" [21] was adopted and modified by Wang [22] to put it in a GIS environment, considering the environmental situation in the study area. Only five geo-genetic indicators were selected (Fig. 3). All indicator maps were reclassified by the scores which should determine the degree of contribution of each class to desertification in the area, as a basin. These classified maps were then integrated in the ILWIS SMCE (spatial multi criteria evaluation) system [23]. The desertification risk could then be evaluated by analysing the resulting intensity map. In order to show the degree and main cause of desertification of each geopedologic unit, the intensity map was zoned by a land unit map, generated from the geopedologic and landscape maps (Fig. 4) [24]. The workshop was wrapped up with reporting. Each participant was asked to conceptualize the situation in his/her country regarding desertification and prepare an essay not only on how to combat it but also on the possibilities to cope (adaptation) with it.

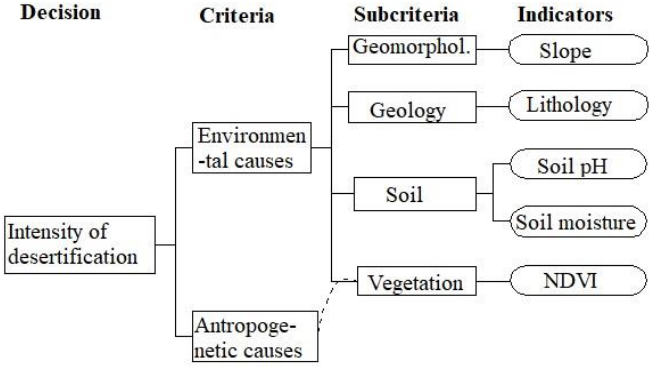


Fig. 3: Desertification assessment model used in Tabernas-Sorbas area, Southern Spain

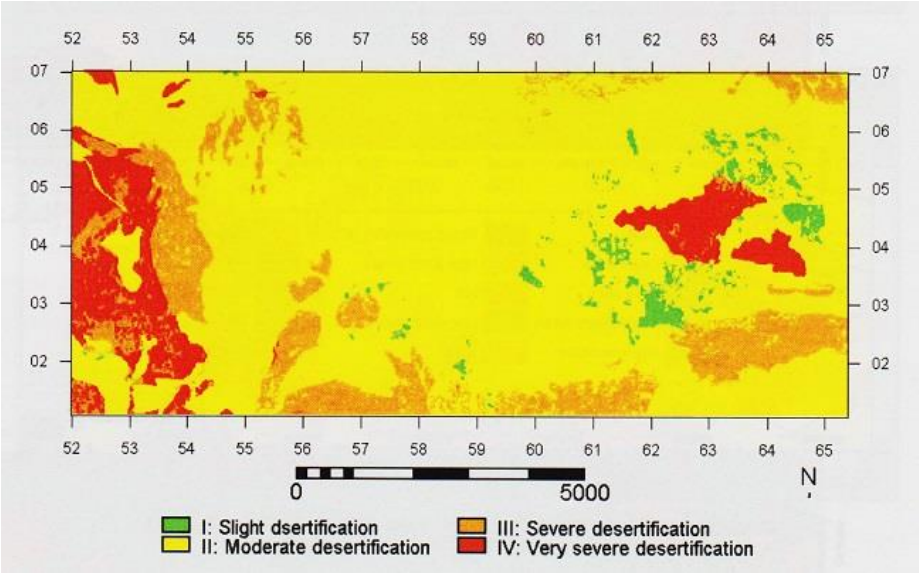


Fig. 4: Desertification intensity map of Tabernas-Sorbas area [22].

3. Results

The prepared essays by the fourteen participants are analysed to illustrate how they, as representatives of several vulnerable countries, think of desertification in terms of natural as well as human-induced factors, causes, combating, mitigation, adaptation, and other related issues.

It is rather remarkable, though not so vital, that the term 'combating desertification' as a key subtitle in the essay is only used by three out of fourteen participants and others have used either 'recommendation' or 'control desertification' as subtitle. Desertification control as defined by FAO is "activity involving the integrated development of land in arid, semi-arid and dry sub-humid zones with the objective of sustainable development, aimed at preventing and/or reducing land degradation, repairing partially degraded land, and at restoring lands affected by desertification". Combating desertification includes on one hand 'mitigation' (eliminating causes of the desertification process) and on the other hand 'adaptation' (coping with the situation). Whatsoever the term, participants, although in different wording, consider the man ('we') not only being the 'victim' but also the 'main agent' of land degradation and desertification, with the simple reason that even when the natural factors are unfavourable, this is the man who is the manager. This is the man who can choose between a short-term policy in an unbalanced- or sustainable use of natural resources.

Another point that participants have anonymously reported, though not always directly, is the role of colonization, such as the case of Nigeria. The lands were cleared of natural vegetation for growing cash crops like cotton, groundnut, and spices. The environment was further devastated by the construction of rail tracts and feeder roads for the evacuation of raw materials from the hinterland to the coast. What the British did in Nigeria and the French, Americans, Soviet Union (Russia), and nowadays Chinese are doing in many African and Asian countries are criticized by the participants. Let's not forget what is said earlier combating desertification requires the contribution of all sectors, national as well as international.

4. Discussion

Desertification has always been a pressing issue among environmentalists, who advocate for its mitigation. However, combating desertification does not imply neglecting existing deserts. In practice, projects aimed at combating desertification often start with stabilizing the borders of existing deserts to prevent further encroachment (Fig. 5).

When damages associated with the sand dune encroachment in different deserts in Iran were noticed by burying infrastructure and farms by sand, endangering food production because of moving sand covering cultivated fields, and the news about trains being derailed, airports being closed, etc. it became imperative to take measures. The first truly serious effort was then initiated in 1965 in a village in the north-east, near the city of Sabzewar, and

on two more plots in the south, near the city of Ahwaz in Southern Iran. These projects yielded successful results that led to an increase in the number of plots spread throughout the country. The measures comprise spraying bitumen, planting woody species such as Atriplex, Holoxylon, Prosopis, and Tamarix, broadcasting seeds of both woody and grass species manually and from aircraft, etc. [25,26]. The project areas were protected, meaning that cultivation and grazing were forbidden. By eliminating the causes (mitigation) native vegetation was so substantially recovered that some areas could become open for controlled grazing and fuel wood gathering.

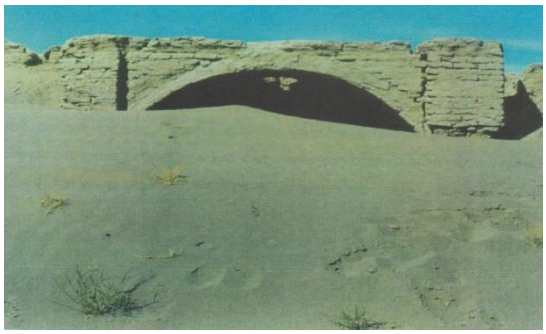


Fig. 5: An example of sand encroachment, Kashan, Iran.

Adaptation, which is these days often recommended regarding 'global climate change' may also be considered as the other pole of the desertification process not only because it connotates copping with the newly created situation, but also as an eye opener to the life of indigenous people in the deserts. The way these people have survived the harsh conditions can be instructive [4]. Isn't it because the inhabitants were not many in number and that they also were blessed with the quality of contentment? Population growth is seen by the participants as the main cause that requires intensive social development far more than family planning services. It requires, among other things, improved food security, improved education, and health services, better security for the elderly people, improvement of women's status through better education and employment, or generally improved socio-economic conditions for vulnerable rural social groups. Obviously, this development cannot be achieved if there is no political will and the rightly elected politicians with ample vision that is fortified by scientific research. The Nigerian policy (introduction of land use decrees of 1976, amended in 1979) on the removal of ownership of land from land users, which led to natural degradation is an example of failure in controlling desertification. In Iran with the setup of the land reform in 1962 [27], several large landlords, owners of sometimes more than one village, were obliged by rule to sell (with crediting via a specially established bank for the purpose) their lands to the farmer tilling the land. This turned out to be a failure. This led to an unforeseen problem, namely disappointment on the side of the great landowners. They started to hesitate about their future and put effort into investing in other sectors rather than agriculture and that resulted in a managerial gap, namely missing the inter-farm managerial role of the great landowner, which must now be bridged by the unprepared farmers. As a result, maintenance of the communal systems such as the system of supplying irrigation water by qanats was overlooked leading to the collapse of many of them [28].

5. Conclosions

Summarizing the opinions of the participants can be done by repeating a few sentences, namely "We people (man) are not only the 'victim' but also the 'main agent' of land degradation that leads to desertification, with the simple reason that even when the natural factors are unfavourable, this is the man ('we') who is the manager". We can choose between a short-term policy, that is what our politicians do to remain longer on the saddle, or to go for sustainable use of the natural resources. Avoiding mismanagement in the use of natural resources and controlling population growth are both in our hands if we think of our children and not only of ourselves. Participants anonymously agree on the fact that for a successful control of desertification stakeholders from all sectors at all levels starting from primary education up to the level of decision-makers should be involved. Obviously, to bring all sectors together, it will need a plan of execution that is supported by the government in each country.

Author Contributions

Conceptualization, A. Farshad, D. P. Shrestha, and M. Abdelfattah; Methodology, A. Farshad and D. P. Shrestha; Validation A. Farshad, D. P. Shrestha, and M. Abdelfattah; Formal analysis, A. Farshad, D. P. Shrestha, and M. Abdelfattah; Investigation, A. Farshad and D. P. Shrestha; Data curation, A. Farshad, D. P. Shrestha, and M. Abdelfattah; Writing—original draft preparation, A. Farshad and D. P. Shrestha; Writing—review and editing, A. Farshad, D. P. Shrestha, and M. Abdelfattah; Visualization, A. Farshad, D. P. Shrestha, and M. Abdelfattah; Supervision, A. Farshad, and D. P. Shrestha; Project administration, A. Farshad and D. P. Shrestha; Funding acquisition, A. Farshad and D. P. Shrestha. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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