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The socio-ecological system of the pre-Sahara zone of Morocco: a conceptual framework to analyse the impact of drought and desertification

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Abstract Drought and desertification have a significant impact on socio-ecological systems throughout the world, particularly in arid and semi-arid regions. In this context, the impact of desertification and drought was analyzed in the pre-Sahara of Morocco. Additionally, a new conceptual framework combining various variables under the context of drought and desertification impacts was developed. The study area has an arid climate and socio-ecological system-based oases. To achieve the goal of the research, a questionnaire was conceived and distributed to a sample of young people (n = 290 on desertification phenomena and n = 290 on drought). A bibliometric analysis was conducted using VOSViewer software to highlight the structure of research and the Likert technique was used as a statistical method to analyze the results. The findings revealed that the respondents reported that drought has a high impact on desertification and sand silting. Otherwise, mental health is highly at risk and drought affects strongly the revenue, yield, and land use. In terms of solutions, the respondents recorded water safe as the appropriate option to adapt to drought in this area. However, in terms of desertification, interviewees thought that temperature and wind have a very high impact on desertification. Roads are the most impacted by sand silting and desertification followed by irrigation canals, and settlements. Concerning the solutions, tourism has a moderate impact on desertification. Young people thereby are aware of the climatic factors and the psycho-socio-economic impacts. They are also able to identify the appropriate solutions to desertification and drought.

Keywords Pre-Sahara · Socio-ecologic system · Oasis biome · Zagora · Morocco

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Abbreviations

APSS	Arab processor in social statistics software
GDP	Gross domestic product

IPCC	Intergovernmental panel on climate change
MDV	Middle draa valley
MGP	Moroccan green plan
UNCCD	United Nations Convention to Combat Desertification

Introduction

Drought is one of the most meteorological extreme events that affect the world community. According to the Food and Agriculture Organization, globally, drought induced 30% of agricultural loss, which was estimated to be over USD 29 billion between 2005 and 2015 (Baas et al., 2018). In fact, this phenomenon affects the availability of water and thus affects global food security, especially in drylands that already suffer from environmental fragility. These drylands cover about 46.2% of the global area including three billion people (Mirzabaev et al., 2019), which increases the exposure. Drought is a complicated and multifaceted natural disaster (Yu et al., 2016), a multivariate phenomenon (Xu et al., 2015), and may affect significant losses in terrestrial ecosystems, agriculture, and social (Byakatonda et al., 2018).

In fact, drought causes agricultural productivity decline (Campbell et al., 2016), desertification (Karmaoui, 2019), and food security (Twongyirwe et al., 2019). The large special-temporal impact of drought increases the losses (Vicente-Serrano & López-Moreno, 2005) and social problems such as unemployment, poverty, and migration. It also affects the economy, especially for countries that depend on agriculture as a basic sector of Gross domestic product (GDP). Morocco is an example of these countries, where the agricultural sector contributes 19% to GDP (Oxford Business Group, 2019). This dependence on the agriculture sector makes Morocco a fragile country towards the phenomenon.

Added to the drought, the deterioration of soil quality, which is manifested by desertification, and then the sand silting that is considered as a result (which increases the frequency of dust storms) is the second most serious hazard. According to Ghadiry et al., (2012), the encroachments of sand dunes are still a major threat in arid desert areas. In 1994, the United Nations Convention to Combat Desertification (UNCCD) defined desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities". The climatic factors comprise precipitation decrease, temperature increase, and droughts are considered the major drivers of desertification (Jiang et al., 2019). In turn, desertification influences seriously both natural resources and human beings (Akbari et al., 2020a, 2020b). The understanding of the factors may play an important role in adequate land management (Akbari et al., 2020a, 2020b) mainly in arid and semi-arid areas of North African countries such as Morocco. This country, suffers from the deterioration of a large area of the national territory. This increases the vulnerability of the country's socio-ecological systems. The southeast of the Kingdom of Morocco, especially the Middle Draa Valley (MDV), is at the head of the most affected areas by the effects of both desertification and drought (Chelleri et al., 2014). This valley is based on subsistence arming, which is based on palm farming and associated crops such as cereals, alfalfa, and some vegetables. This makes the area more vulnerable to both drought and desertification.

To study these two phenomena, an analysis of their impact on oasis systems as well as their associated rangelands was carried out. This is done by presenting the most important variables of these systems and integrating them into a single conceptual framework.

This current study is a continuation of the first part of a research project conducted by Karmaoui, (2019), that analyzed 17 variables for the two phenomena, namely groundwater and surface water scarcity, water and soil salinity, overgrazing, deforestation, Bayoud disease, transhumant, population growth, migration, schooling, health service, school service, drinking water service, electricity service, production of organic fertilizers, and seasonal migration.

The novelty of the present study added 17 new variables that are important to complete the whole picture of the causes-effects of both drought and desertification. In fact, nine variables for drought phenomenon including sand silting and desertification, gender, psychological exploitation of forests and pastures, revenue reduction, yield reduction, land use (crops), safe water, diversification of activities (tourism, crafts…) were used. Added to these determinants,

seven new variables were analyzed comprising temperature, rainfall, winds, fertilizer use, irrigation canals (modern and traditional), settlements, roads and tracks, and tourism.

The outputs may allow supporting the decision-making regarding the sustainability and resilience of these systems. The study aims to analyze the effect of the two phenomena in the MDV by proposing a new conceptual framework dealing with the socio-environmental system of desert environments.

Literature review

West et al., (2019) defined drought as a pervasive global hazard hydrometeorological event that will become more frequent and intense, raising the importance of effective drought monitoring. Otherwise, Zhao et al., (2020) classified the drought into three types namely: Drought exposure including population and proportion of cropland and pastureland; Drought vulnerability comprising Water pressure and proportion of irrigation area to cropland; and drought loss associating Economic loss (Drought affected population and cropland). The influence of drought plays a crucial role in socio-ecological system studies in semiarid and arid zones and its assessment provides new thinking for the system sustainability (Shi et al., 2019). In this context, Berrouet et al., (2018) identify the interactions of the variables of the vulnerability of the social and ecological dimensions, determining and improving those that reduce vulnerability. The variables linked to drought are numerous and have a considerable effect on the socioecological system such as water resources (Stewart et al., 2020), vegetation cover (Toigo et al., 2015), agriculture (yield, and cropping type) (Fraser et al., 2008), etc. In the last thirty years, the average temperature was increased and the rainfall has decreased, which raises the area under dry conditions. Most of this area is as well as under desertification processes. Liang et al., (2021) advanced that desertification is the result of the conjugated effects of both natural and human drivers. However, the Intergovernmental Panel on Climate Change (IPCC) reported with high confidence that the risks from desertification are projected to increase due to climate change (Mirzabaev et al., 2019). This association between dry conditions, drought, and desertification was demonstrated in Akbari et al., (2020a, 2020b).

The bibliometric analysis (see details in Material and methods section) highlighted the most important concepts related to the impacts on drought and desertification and the socio-ecological system in dryland. The first group of key terms on drought and desertification in dryland (Fig. 1) explore the followings concepts: Climate change, rainfall, land degradation, soil erosion, irrigation, land use, forest-deforestation, conservation, land management, sustainability, vegetation, water supply, water resources, agriculture, and soils.

The second group (Fig. 2) highlighted the key terms socio-ecological system, dry land, drivers, soil conservation, runoff, agroforestry, indigenous knowledge, soil fertility, crop residue, drought, cash cropping, microclimate, Animalia, land management, productivity, alternative agriculture, erosion, vulnerability, food supply, food security, dryland farming, decision making, sustainable development, drylands, and seasonality.

The third cluster (Fig. 3) associated the key terms agriculture, water supply, biodiversity, soils, shrub, deforestation, decision-making, soil moisture, demography, emigration, immigration, migration, salinization, and irrigation.

To summarize, based on this review, previous attempts to study desertification and drought separately were found, but to our knowledge, few of them explored both phenomena using multivariable assessment. In this study, we develop a new conceptual model that includes a set of variables presented and discussed below.

Material and methods

Study area

This study was carried out in the MDV (Fig. 4), which is located in the southeast of the Kingdom of Morocco and extends over an area of 15,000 square kilometers (Klose, 2009). This valley is characterized by arid to hyper-arid climatic conditions (Johannsen et al., 2016) and an elevation ranging from 375 to 1020 m above sea level. The annual precipitations reache 200 mm in the north and 30 mm in the south, with average potential evaporation of 3000 mm (Klose, 2012). The

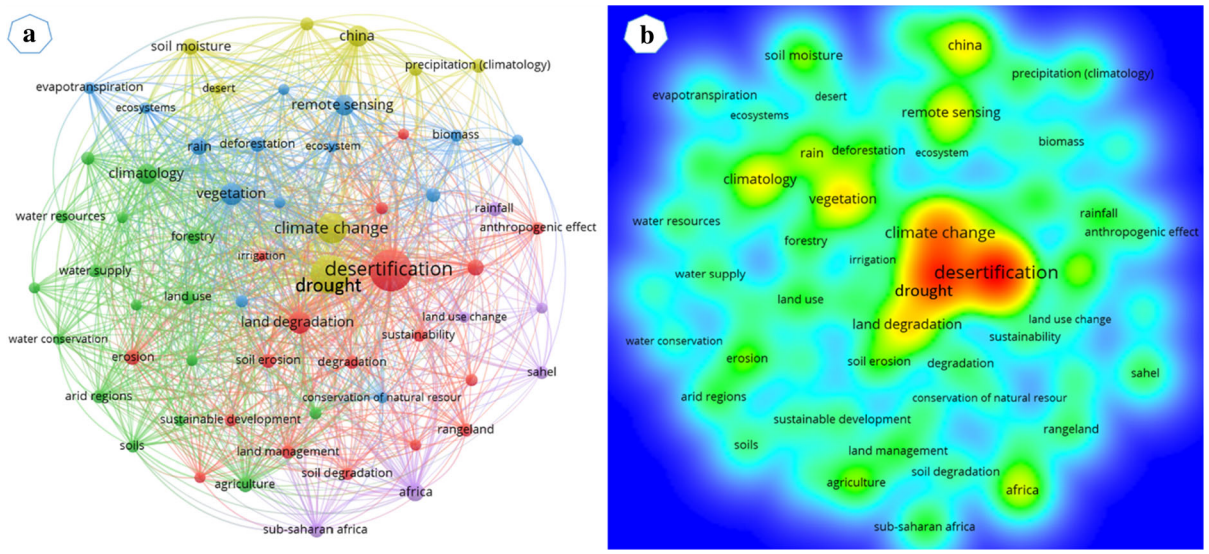

Fig. 1 The first group of papers on drought and desertification in dryland using VOSViewer

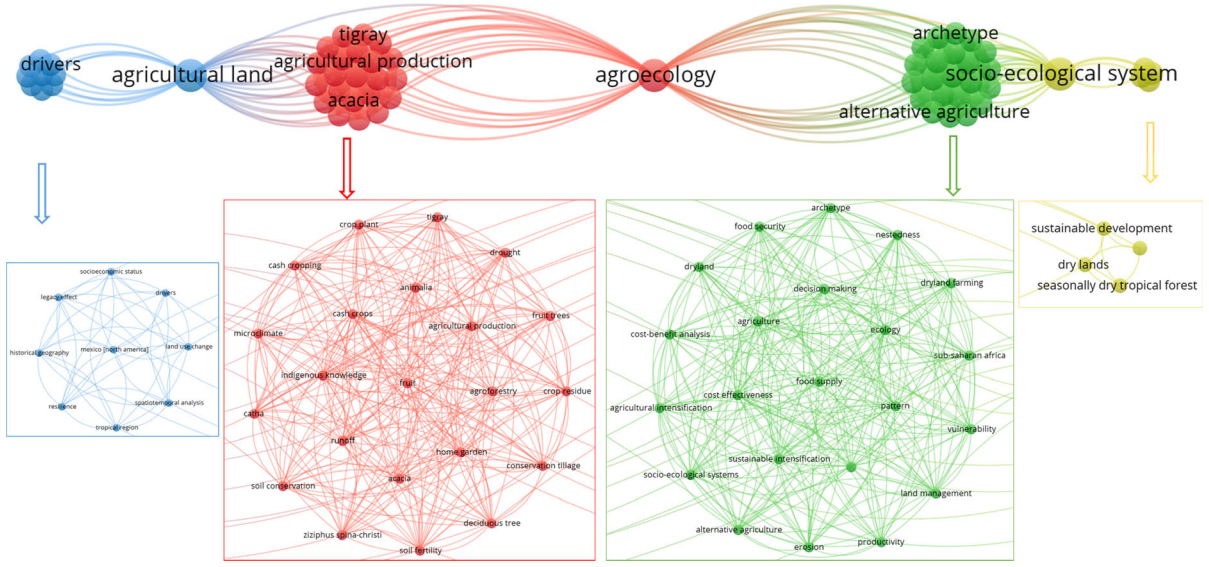

Fig. 2 The second group of papers on socio-ecological system using VOSViewer software

average temperature is approximately 35 °C, with a maximum temperature in summer exceeding 45 °C and less than 0 °C winter nights.

The region relies on Mansour Eddahbi Dam (MED) as the main source of water, with a storage capacity of more than 250 million cubic meters. Water is distributed in the form of releases through Wadi Draa, which feeds both the six oases of the basin (Mezguita, Tinzouline, Ternata, Fezouata, Ktaoua, and M'Hamid) and the associated aquifers along the basin from northwest to southeast direction. The region depends on the water stored in this dam, which comes from precipitation in the Upper Draa Valley that reaches its highest elevation peak 4 071 m above sea level at the M'Goun summit (the eastern slope of the High Atlas). Any decrease in precipitation in the High Atlas Mountain may affect greatly the MDV, especially in the agricultural sector, which is reflected in the human well-being of the region. In fact, in the last 30 years, water availability

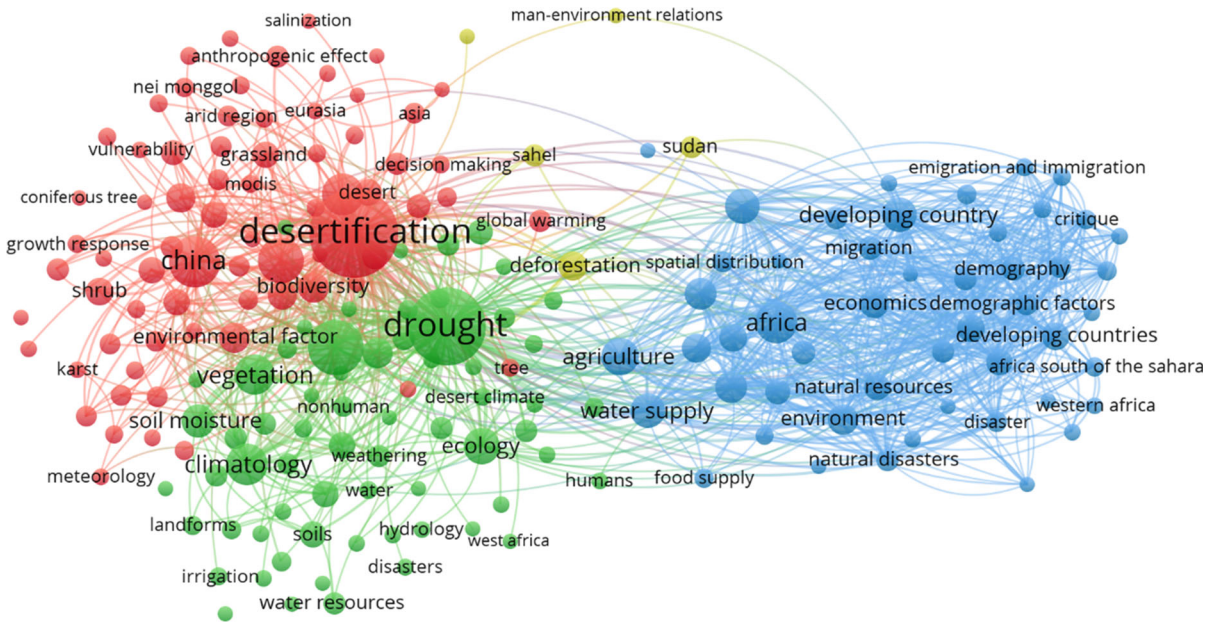

Fig. 3 The third group on desertification, drought, and factors using VOSViewer software

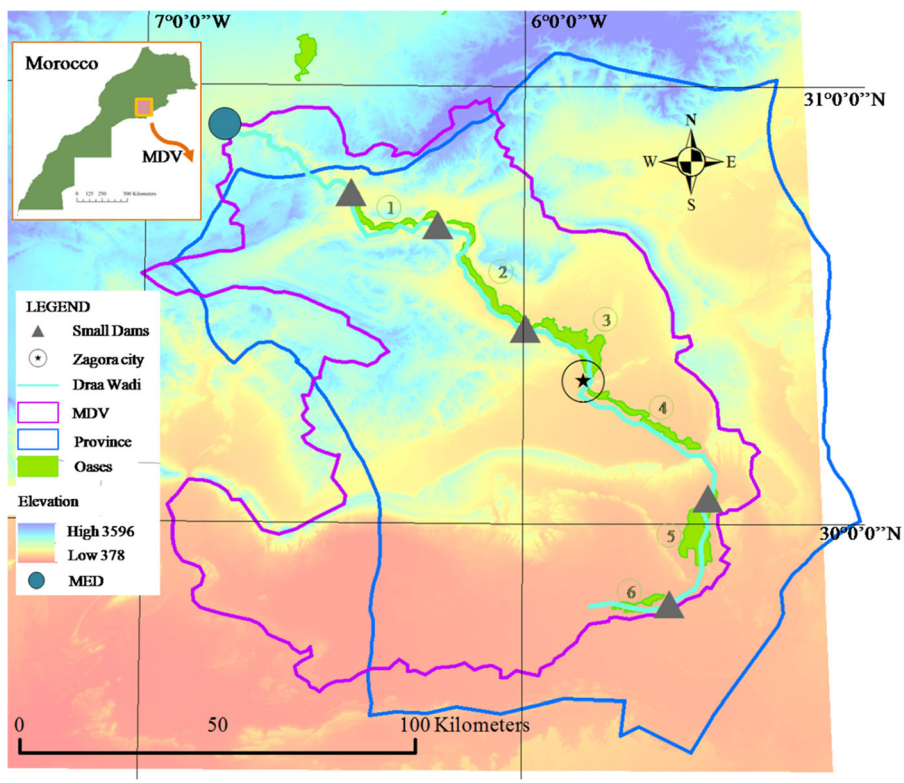

Fig. 4 Localization of the study area, the elevation and delimitation of the Middle Draa Valley (MDV) and the province (administrative division) in Southeastern Morocco. MED, Mansour EddahbiDam; Numbers refer to the six oases: 1, Mezguita; 2, Tinzouline; 3, Ternata; 4, Fezouata; 5, Ktaoua; and 6, M'Hamid

was declining because of the frequent droughts, particularly, the groundwater for the six palm groves of the MDV (Karmaoui et al., 2019). The area of oases is very small compared to the total area, as it does not exceed 25,000 hectares, which represents less than 0.1%. This makes most of the area without permanent vegetation and this increases its exposure to desertification as well as drought. In addition to the agricultural sector, the region depends on migration and the tourism sector as a source of income.

Bibliometric analysis

To reflect the structure of research about drought and desertification in dryland and socioecological system in dryland, a bibliometric analysis was conducted based on Scopus database using VOS-Viewer software. Three groups of papers were gathered and analyzed. The first group comprises 295 documents that were retrieved for the key terms drought and desertification in dry land in the period 1978–2020 until June; the second group included seven documents for the key terms socio-ecological system, dry land in the period 2017–2019; and the third group associates 324 using the key terms desertification, drought, factors in the period 2017–2019, 324 documents were retrieved.

The first group of papers using the terms drought and desertification in dryland based on the information of 295 papers, where from 2418, 63 terms meet the threshold with an occurrence of five terms (all the 63 terms were considered). However, the second group of papers using the key terms socio-ecological system, dryland in the period 2017–2019 based on the information of 324 papers, where from 2843 keywords, 196 terms meet the threshold with an occurrence of 5 terms (all the 196 terms were considered). In regard to the third group, it associates 324 using the key terms desertification, drought, and factors in the period 2017–2019, 324 documents were retrieved.

Data and method

This study was based on the results of a sample of 580 questionnaires: 290 young people for desertification and 290 for droughts.

This study was based on the results of a sample of 580 questionnaires: 290 young people for desertification and 290 for droughts. A group of questions including factors, consequences, and some solutions for both phenomena were asked. With regard to drought, multiple questions were included according to the degrees of impact (rating scales varies from low, middle, high, and very high impact) and they were about sand silting and desertification, gender, human psychology, exploitation of forests and pastures, revenue reduction, yield reduction, land use (crops), safe water, and diversification of activities (tourism, crafts, etc.). However, for desertification, the questions related to climatic factors such as temperature, rainfall, winds, and to physical factors include fertilizers use, irrigation canals, and seguias, settlements, roads, and tracks, and economic factors such as tourism. Questions were also raised regarding some proposed solutions to alleviate the two phenomena.

To analyze the results, a Likert statistical technique was applied. It allows studying the relative importance of a variable. The range of numerical values uses four points and the following Eq. (1):

$$V_x = \frac{\sum w}{N} = \frac{4n_4 + 3n_3 + 2n_2 + 1n_1}{N} \quad (1)$$

where; V_x: impact points of a given variable; w: total score; n_1: number of responses for low impact; n_2: number of responses for middle impact; n_3: number of responses for high impact; n_4: number of responses for very high impact; N: Total number of the responses.

This study is part of the project studying the phenomena affecting socio-ecological systems in the oases of Morocco (Karmaoui, 2019). In this study, we attempt to design a conceptual model around the two phenomena, which includes the main variables and the extent of their impact on different aspects of the socio-ecological systems of the region. Conceptual models are scientific methods that allow the simplification of the understanding of complex systems. They also allow for clarifying possible relationships between individuals and groups of variables. As such, they are essential to intervene, understand, and solve complex problems in socio-ecological systems. They are considered good and useful techniques to support decision-making. The choice of variables used was based on the general structure of the conceptual model represented in Fig. 5.

Based on the youth's opinions, new impact factors, consequences, and solutions were identified. Together, these variables were organized in a single

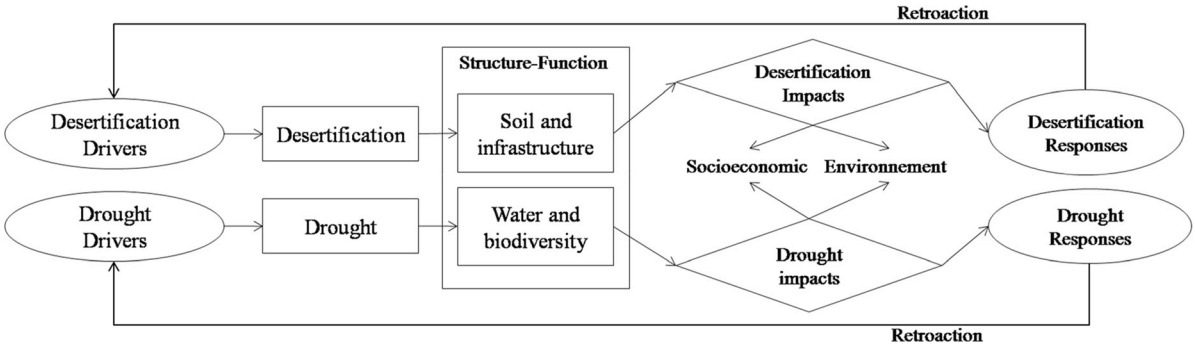

Fig. 5 General structure of the conceptual framework of drought and desertification impacts in the Middle Draa Valley

conceptual model. The general structure of this model explores how drought and desertification influence the structure and function of the oasis system through the water, soil, biodiversity, and infrastructure. This generates socioeconomic and environmental effects that will, in turn, impact the social responses. These responses may react to accelerating or regulating the initial drivers of both drought and desertification.

Results

The statistical analysis estimates young people's knowledge of drought and desertification in MDV. A sample of 580 young people was interviewed in total to rank some types of variables regarding the effects, the consequences, and some solutions to the two phenomena.

Socio-economic impact of drought in pre-Sahara of Morocco

According to the young interviewees (Tables 1 and 2), drought has a direction of very great (35%) to great (33%) impact on desertification and sand silting. For women's participation, there is a low (42%) to middle impact (24%), with a direction toward moderate impact. For the psychological factor, opinions differ, but with a tendency of high impact. The exploitation of forest wood and pastures was impacted moderately (29%) to highly (27%), with a direction towards a high impact. Regarding the economic consequences (Tables 1 and 2), for the reduction of income, the young respondents identified a high (32%) to medium (31%) impact, with a high impact direction of drought. However, the reduction in agricultural yield was very high (42%) to highly (31%) impacted, with a high impact in general trend. Land use (types of the crop) has been highly (32%) to very highly (36%) impacted, the statistical method revealed a direction of high impact. For solutions (Tables 1 and 2), water-saving was mentioned as very highly (29%), to moderately (26%) impacted, with a statistical direction towards a high impact. Otherwise, diversification of activities has been identified as having a low (36%) to medium impact (26%), with a moderate impact on the reduction of the drought effects.

Socio-economic impacts of desertification in pre-Sahara of Morocco

The findings show (Tables 3 and 4) that according to the young interviewees, the temperature has a very high (52%) to high (35%) impact against an average (9%) to low impact (3%) with a general direction of a very large impact. For precipitation, the young interviewees reported that precipitation has a low (40%), average (24%), high (15%), and very high impact (21%), with a general statistical trend toward an average impact. However, winds have very large (31%), high (31%), medium (32), and low (5%) impacts on desertification and sand silting, with a general direction towards a very high impact. The use of chemical fertilizers has a high impact (36%), medium (32%), very high (17%), to low (15%) impacts, with a high impact direction. For the consequences of the desertification and sand silting (Tables 3 and 4) on roads, agricultural infrastructures, and agglomerations (settlements), in general, an average to high impact was noted. Lastly, for the solutions, tourism has a moderate impact on desertification and sand silting.

Table 1 Percent of the young people responses on drought in Middle Draa Valley

Drought variables	Low	%	Middle	%	High	%	Very high	%	Sample
Sand silting and desertification	13	5	72	27	90	33	96	35	271
Gender	120	42	69	24	50	18	46	16	285
Psychological	57	21	75	27	64	23	80	29	276
Exploitation of forests and pastures	59	20	83	29	79	27	69	24	290
Revenue Reduction	38	13	90	31	93	32	68	24	289
Yield reduction	19	7	60	21	90	31	121	42	290
Land use (crops)	35	12	55	19	93	32	104	36	287
Safe water	62	21	76	26	69	24	83	29	290
Diversification of activities (tourism, crafts)	104	36	75	26	50	17	57	20	286

Table 2 Responses of the interviewees on drought in Middle Draa Valley

Drought variables		Low	Middle	High	Very high	Sample	Data %	Arithmetic average	Standard deviation	%	Sample Direction
Physical factors	Sand silting and desertification	13	72	90	96	271	93,4	2,01	0,9	50,25	High
Social factors	Gender	120	69	50	46	285	98,3	2,92	1,11	73	Middle
	Psychological	57	75	64	80	276	95,2	2,39	1,11	59,75	High
Access to services	Exploitation of forests and pastures	59	83	79	69	290	100,0	2,46	1,06	61,5	High
Economy	Revenue reduction	38	90	93	68	289	99,7	2,34	0,98	58,5	High
	Yield reduction	19	60	90	121	290	100,0	1,92	0,94	48,25	High
	Land use (crops)	35	55	93	104	287	99,0	2,07	1,02	51,75	High
Drought solutions	Safe water	62	76	69	83	290	100,0	2,4	1,11	60	High
	Diversification of activities (tourism, crafts)	104	75	50	57	286	98,6	2,79	1,14	69,75	Middle
General average								2.37	1.09	59.25	High

Table 3 Percent of the young people's responses on desertification in Middle Draa Valley

Desertification variables	Low	%	Middle	%	High	%	Very high	%	Sample
Temperature	10	3	27	9	101	35	151	52	289
Rainfall	110	40	65	24	42	15	56	21	273
Winds	15	5	94	32	90	31	91	31	290
Fertilizer use	43	15	89	32	102	36	48	17	282
Irrigation canals and seguias	83	29	90	31	66	23	50	17	289
Settlements	32	12	119	43	96	35	31	11	278
Roads and tracks	61	21	77	27	70	24	80	28	288
Tourism	102	36	86	30	61	21	38	13	287

Table 4 Responses of the interviewees on desertification in Middle Draa Valley

Desertification variables		Low	Middle	High	Very high	Sample	Data %	Arithmetic average	Standard deviation	%	Sample Direction
Climate	Temperature	10	27	101	151	289	99,7	1,64	0,79	41	Very High
	Rainfall	110	65	42	56	273	94,1	2,84	1,16	71	Middle
	Winds	15	94	90	91	290	100,0	2,11	0,91	52,75	High
Social factors	Fertilizer use	43	89	102	48	282	97,2	2,45	0,94	61,25	High
Consequ-ences	Irrigation canals and seguias	83	90	66	50	289	99,7	2,71	1,06	67,75	Middle
	Settlements	32	119	96	31	278	95,9	2,55	0,84	63,75	Middle
	Roads and tracks	61	77	70	80	288	99,3	2,41	1,11	60,25	High
Desertification Solutions	Tourism	102	86	61	38	287	99,0	2,88	1,04	72	Middle
General average								2.45	1.06	61.25	High

The conceptual framework

Some key variables were ranked by the young people of the study area to depict some social and economic impacts of drought and desertification. A conceptual framework has been proposed to group the key findings of the survey (Fig. 6). Only variables ranking moderate, high, and very high impact scores were used, which allows selecting only the most appropriate impact variables.

The main socio-economic changes under desertification and drought conditions were identified by the young people. For drought phenomena, precipitation is evidently the main factor conditioning the drought occurrence. In the case of a dry year or period, water availability decreases, which influences biodiversity, mainly, the vegetation cover, and this affects human well-being. Gender, mental health (psychological aspect), income reduction, yield decrease, and cropping changes are some socio-economical impacts that were recorded. In addition, overuse of forest and

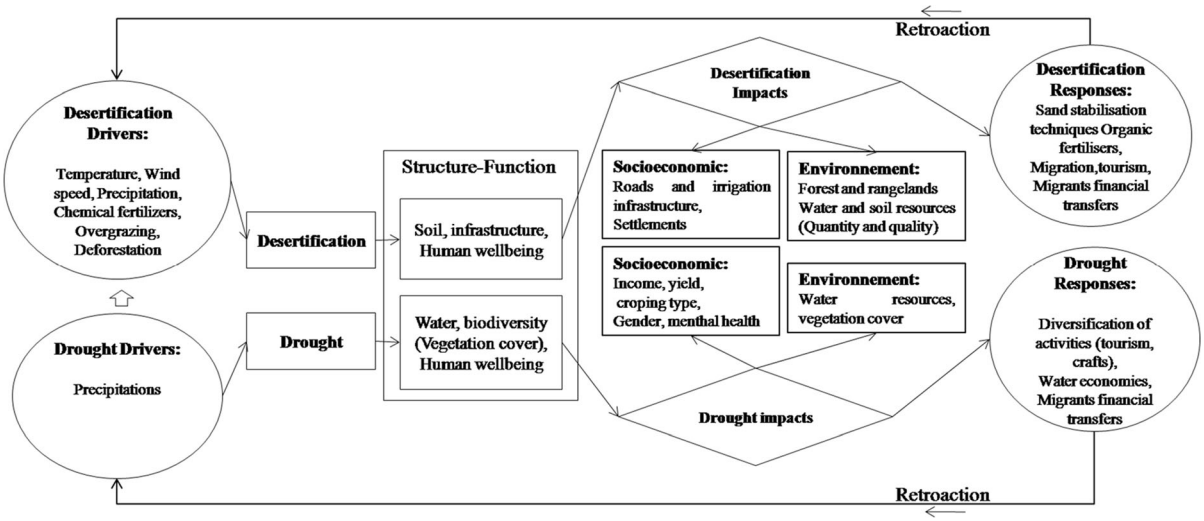

Fig. 6 The general structure of the conceptual framework of drought and desertification impacts in the Middle Draa Valley

rangeland's resources and water were identified as high ecological impacts. However, the diversification of activities (tourism, crafts) and water economies may be used as effective responses to drought effects. Otherwise, drought was identified as contributing high factor to desertification and then sand silting (see results, Table 2). The most commonly identified drivers affecting desertification was the temperature, wind speed, and precipitation for the climatic factors, particularly temperature that was ranked as having a very high impact. Additionally, the impact of overgrazing and deforestation that were reported by Karmaoui, (2019), the excessive use of chemical fertilizers was also identified as a high impact driver. Together, these factors interact in a complex way to influence soil and infrastructure and then the well-being of the local population. Among the main effects, roads and irrigation infrastructures, and settlements are some socio-economic examples that were ranked to have the high impact. Forest and rangelands, water and soil (quantity and quality) were identified as ecological components the most impacted. In the fight against desertification, and the use of mechanic and biologic sand stabilization techniques, organic fertilizers, migration financial transfers, and tourism can be considered as important options that can control or regulate the initial desertification drivers.

Discussion

The effect of drought leads to significant challenges to agricultural production (Sharafi et al., 2020). This productive sector is placed at the center of the socio-ecological system of the Middle Draa Valley and is threatened by advanced desertification. In fact, the study area suffers from drought followed by desertification as major threats (Karmaoui, 2019). As the most productive sector is affected, other associated sectors are as well as influenced, namely, the economic, social, environmental, cultural, food security, and trade, etc.

Drought in pre-Sahara of Morocco.

In terms of drought, the finding revealed a high impact on desertification and sand silting. This was in accordance with the results of Karmaoui, (2019). Both drought and desertification have a considerable impact on water and soil ecosystem services. This is through the reduction in the quantity of water, and consequently the depletion of the vegetation cover and then the reduction in soil quality. The agricultural, forest, and rangeland's systems productivity are important in feeding both human and ruminant animals. In fact, according to the young people surveyed, drought has a very high impact on the reduction of agricultural yield and a high impact on forest wood and pasture (rangelands) exploitation. Indeed, the phenomenon causes considerable agricultural losses (Lesk et al., 2016). This, in turn, influences the economic sector of the region. The young people expressed this impact ranking a high score on the reduction income of the local population. This can be explained by the high dependence of the population on agriculture as the first source of revenue, and this sector is the main economic sector (70%). Additionally, 92% uses woods as the first energy source in the commune of the sample according to the last population and housing census of the Moroccan High Commission for Planning, Morocco (HCP, 2014). Otherwise, drought may influence highly the type of cropping as estimated by the *Likert* analysis. Moreover, the economic impact, in the period of drought, some social changes were found concerning gender (Tichagwa, 2007) and psychological aspects (mental health exposure) (Berry et al., 2010). In fact, the respondents ranked a high impact of drought phenomena on the psychology of the population. This is in accordance with the findings of Obrien et al., (2014) reporting that a seven-year period of drought was associated with increased distress for rural dwellers. In this context, the young interviewees reported a high impact of drought on the psychological health of the local population. This can be supported by the orientation trend of young people to migrate toward the big cities and abroad. The influence of drought on women is the second aspect highlighted as a moderate impact. Ncube et al., (2018) reported also that women are vulnerable to drought and advanced that the poor soils and lack of property ownership, low education levels, and unemployment accelerate the women's vulnerability to drought. In middle Draa Valley, and precisely in the Bni Zoli Commune, the illiteracy rate is about 48.9% among women versus 22.3 for men, and 9,337 of women are inactive compared to 5,255 for men (HCP, 2014). This difference can support associations between women and drought.

Regarding the solutions for the respondents, water economics may have a high impact on drought. In fact, according to Berbel and Esteban, (2019), users in water-stressed zones have generally adapted to water scarcity. The supply-side mechanisms were used as a method to prepare for droughts (Gleick, 2003). The saving water project was initiated also by the Moroccan Green Plan (MGP) that subsidizes a large part of the drip-by-drip technique in irrigation. Diversification of economic activities has been identified as having a moderate impact on the reduction of drought effects. This is in accordance with Parker (2015) that advanced that economic diversification reduces the sensitivity of agriculture to drought. In the study area, an increase of dry years trend was projected to occur in the twenty-first century both under IPCC-A2 and B2 (Karmaoui et al., 2019), which increases the risk and this predisposition alludes to the need to reinforce the sustainable use of the ecosystem services, mainly land and water resources.

Desertification in pre-Sahara of Morocco

Desertification is the second greatest challenge after drought in the study area (Karmaoui, 2019). According to Wang et al., (2009), three climatic factors of desertification were used, namely temperature, rainfall, and wind speed. Costa & Soares, (2012) explored the considerable role of climate change in desertification. According to the data analysis, the young interviewees ranked temperature and wind speed as the very high impact that accelerates desertification processes. However, precipitation has a statistical trend toward an average impact. Regarding the anthropogenic factors, in addition to the impact of overgrazing and deforestation explored in Karmaoui, (2019), the excessive use of chemical fertilizers has a high impact on desertification in the study area. This was already advanced also by Katyal & Vlek, (2000) reporting that using chemical fertilizers instead of organic manures causes nutrient deficiencies and soil fragility. This can exacerbate land degradation and desertification mechanisms. For the consequences of the desertification and sand silting on roads, agricultural infrastructures (irrigation canals), and agglomerations (settlements), in general, an average to high impact was noted by the young people. Ghadiry et al., (2012) considered the movements of the sand dunes as a menace for these urban and agricultural facilities. To fight against desertification and sand silting, many strategies may be used. The use of organic fertilizers (Karmaoui, 2019) is an example. These organic fertilizers include animal manure, compost, and crop residues are important elements that promote soil quality (Frossard et al., 2009) and then support biodiversity (Tong et al., 2019). For desert sand dunes, there are three categories of fixation systems, mechanical, biological, and mechanical–biological, and the respondents ranked seasonal migration as an option that has a moderate impact on desertification. This can be supported by the dependence of the local population on financial transfers by migrants (Karmaoui et al., 2015).

Moreover, the positive effect of out-migration that alleviates the pressures on areas affected by desertification (Knerr, 2004), the seasonal migrants support greatly their families stayed in the vulnerable regions (Pearson & Niaufre, 2013). This migrant's financial assistance may be considered an option to diversify livelihood income (Jónsson, 2010). Taken together, the knowledge of young people has real potential to improve our understanding and surveillance of both drought and desertification at a local scale.

Young people demonstrated an understanding of the drivers, socioeconomic and environmental effects of both drought and desertification. The young people clearly linked the climatic and anthropogenic determinants to the local human well-being and are aware of the environmental and socio-economic conditions they suffered. They are also clear on the solutions to implement in order to decrease the risk of the two phenomena. While not all young people explicitly identified the other factors as high impact drivers, socioeconomic, and environmental effects of drought and desertification, these variables were evident throughout the previous studies. This reaction of the young people regarding the two phenomena can be reinforced by new scientific projects based on local participative workshops and expert opinions to support and refine the findings of the proposed framework.

Overall, the following options are recommended:

- Combine traditional and modern knowledge (drip irrigation and varieties selection);
- Economic diversification;
- Sensitize and educate about the importance of soil and water ecosystem services;

- Afforestation
- Water, soil, and vegetation cover conservation;
- Desert forest and rangelands management;
- Reduce the chemical and adopt organic fertilization

Conclusion

The current study was based on the identification and ranking of the impact of some socio-ecological factors of both drought and desertification. In terms of drought results, the respondents reported that the human psychology is highly at risk and the women are moderately at risk and suggest that drought affect highly the revenue, yield, and land use. Concerning solutions, young people recorded that safe water has a high impact and the diversification of economic activities has a moderate impact on the drought phenomenon. However, in terms of desertification, young people think that temperature and wind have a very high impact on desertification and sand silting. Roads are the most impacted infrastructures by sand silting and desertification followed by irrigation canals and settlements. For the solutions, tourism has a moderate impact on desertification. These variables (and other variables that are evident throughout previous studies.) were integrated into a new conceptual framework to enable decision-makers to implement the appropriate response.

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