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Land-use change and sustainability in the south-eastern oases of Morocco

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Abstract. The study apprehends modern versus traditional land-use changes in the Moroccan oases. The traditional local knowledge and land-use that ensured ecological equilibrium for centuries is decreasing. Modern entrepreneuship practices are increasing and have risky environmental impacts.
By using the spatial and factor analyses, we confirm the spatial disparities in the region and distinguish four different groups of communes (in high mountain communes, traditional agriculture favors resources' conservation; downstream communes experience greater changes and ecological ruptures). The recommendations of the study include the need to rethink adopted development models and elaborate new actions that respect local specificities, consider environmental equilibrium and rehabilitate local ecosystems.

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1. Introduction

All over the world, most oases are presently under environmental stress (Postel, 1992). Desertification is activated by climate change, inducing water scarcity and land degradation. The recent negative impacts of climate change are confirmed in multiples oases over the world (Imaz-Lamadrid et., 2020). Verstraete et al. (2008) consider climate change to be a factor in the future degradation of drylands. Their environmental apprehension needs a comprehensive approach linking the study of environmental and socio-economic problems in drylands in an interdisciplinary way. In the past, the indigenous knowledge and inherited intellectual capital served balanced land use in oases (Davis, 2005; Brooks, 2006; Rusu-Tanas, 2015). The importance of intellectual capital in local sustainable development is recognized by several authors and international organizations (World Bank, 2006; OECD, 2013; Tian et al., 2018; Giustina et al., 2020; Popoola & Magidimisha, 2020). This heritage is progressively shifting (Fassi, 2017; Lavie & Anaïs, 2017). Inappropriate modes of resource exploitation contribute to land degradation and influence the business of local communities (Blaikie, 1973; Hakikur, 2006; Kamaoui, 2019).

In the Moroccan oases, a dynamic environmental equilibrium was achieved in the past due to specific local knowledge of environment (Blaikie, 1973; Daoud, 2001). The traditional agriculture includes historic agrosystems adapted by local societies to meet their nutritional and/or trading needs. They represent time-tested, sustainable approaches (Ellis and Wang, 2011). Traditional resources management in oases have favored practices that maintain agricultural biodiversity (Aksoy & Oz, 2020) and ecosystem rehabilitation (Madejón et al., 2011). It reinforces the connectivity of green landscapes (Skokanová et al., 2020) and sustains groundwater (Bouimouass et al., 2022). Such agrosytems in oases facilitate trans-Saharan trade and allowed the development of cities and historic business centers of visible cultural influence such as Tombouctou and Sijilmassa. However, successive droughts and recent socio-economic evolutions that neglect the benefits of natural resource renewal threaten the balanced equilibrium that has been built throughout the centuries (Bencherifa & Popp, 1992; Davis, 2005; Ait Hamza et al., 2010). Faced with modern technological growth in land use, a loss of skills for rational environmental adaptation is observed in the actors at several parts of oases. This is influenced by external inputs and investments. The fundamental ecological equilibrium that had previously ensured land use sustainability and cultural landscapes in the oases is progressively being neglected. Current land uses, business models, technologies, visions and aspirations of residents are becoming different from those of the ancestral generations and are generating quite negative impacts on the environment (Thomas, 2008; Hamamouche et al., 2018). Indicators of contrasting sectors within selected oases in south-eastern Morocco were investigated in the present research. We aim to understand the drivers, processes and spatial indicators of recent land-use change in oases. The apprehension of future trends is important in order to envision their potential agri-environments schemes and their roles in sustainability development.

Several questions were raised in this research:

1. How are the ongoing modern land use changes spatially structured?
2. How are they challenging environmental equilibrium and sustainability?
3. To what extent does the shifting traditional land use and way of life, in parallel to the growing modern investments and technologies introduced in oases, impact their environment?
4. Do these technologies and new investment methods create sustained wealth in oases?

The change indicators and drivers are studied considering their spatial distribution, temporal evolution and trends. How are they perceived by actors? A particular focus was put on identifying useful keys for future strategies and actions to reinforce ecosystems, improve water-use efficiency and achieve the sustainable development of oases.

2. Material and research methods

2.1. Study area

The studied area includes the overall territory of the Draa-Tafilalet region (Fig. 1), where several oases developed, especially along the "wadis" that drain the southern flanks of the High Atlas Mountain and its piedmont.

We focus on the Ziz, Ghris, Todgha, and Dades valleys, where observed dynamics of land-use change are significant but contrasted. Several sectors where traditional agriculture and inherited activities are still dominant in the upstream valleys, but downstream valleys are experiencing advanced modernization and urbanization. The demographic and socio-economic evolution and the ongoing

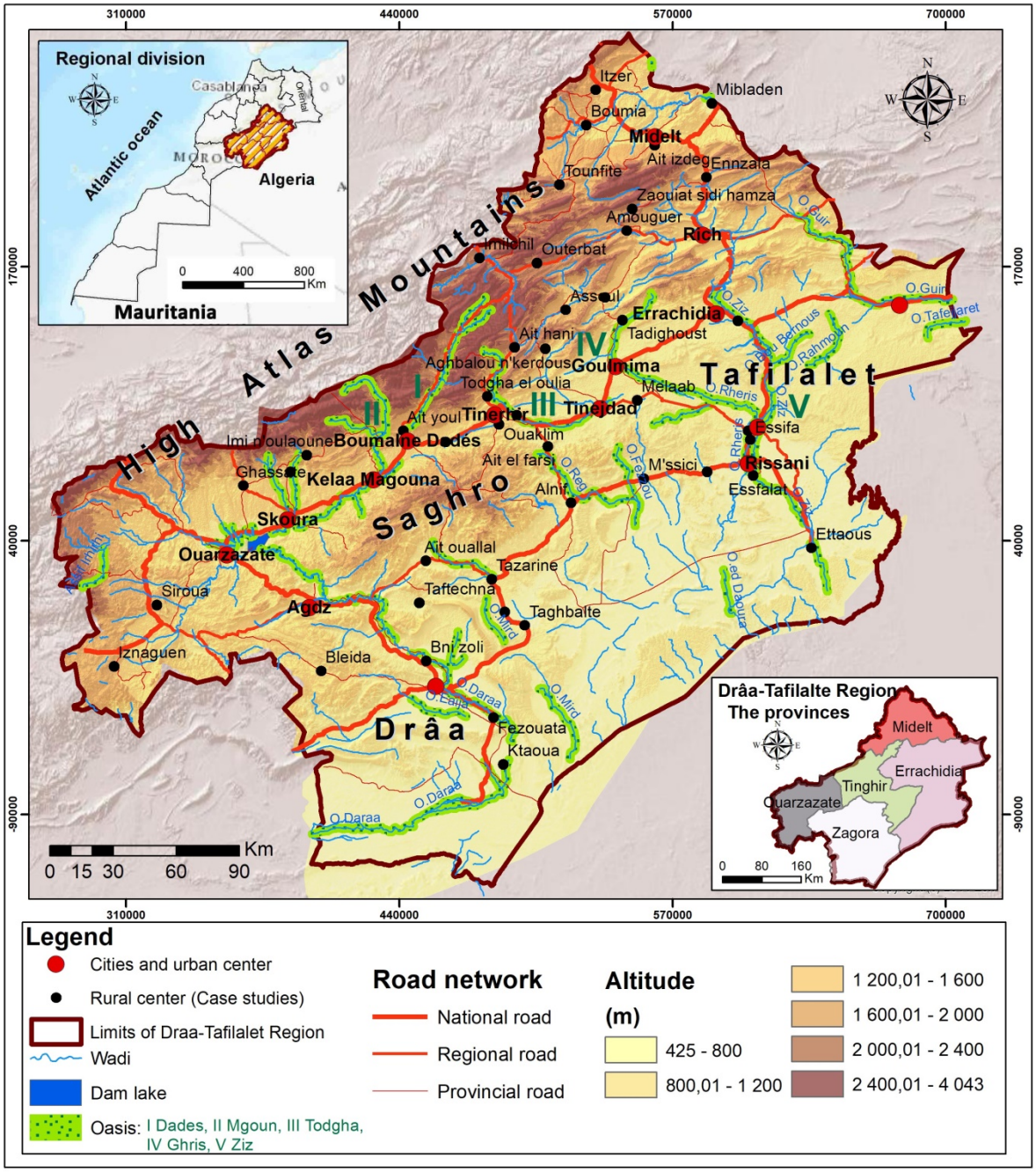

Fig. 1. Study area and its administrative framework
Source: author

climatic changes are commonly drivers of landscape change (Haas, 2006; Sabiri, 2020). These changes are influencing land use and generating diverse rural territories.

To illustrate this diversity and demonstrate the recent deterioration in the balance of environments, the study focuses on several areas where preliminary fieldwork has shown evidence of contrasting characteristics, as follows:

(I) the areas of traditional and rural activities in valleys, including the isolated oases at the piedmont of the Saghro Mountain and the southern flanks of the High Atlas. Most of them are less influenced by modern types of land use and sophisticated modes of resource exploitation. Techniques for conserving cultural heritage and resources are prevalent.

(II) the most modernized areas with new farming investments and recent extensions of the oases. Traditional agriculture is being considerably weakened and alternative activities such as trade, enterprise and other employment sectors with different modes of resource consumption are being

developed. Rural communes representing such areas in the Ziz, Ghris, Dades, and Mgoun valleys are selected for study.

(III) transitional spaces, where land use is influenced by proximity to sectors deeply affected by modern changes but inherited practices are still dominant. The rural population is mainly concentrated in *douars* along mountain valleys and oases. The traditional economy is still maintained but several rural communes are experiencing modern activities, mainly small urban centers (Montasser, 1985; Carpentier & Gana, 2017).

The observed landscapes' diversity is due to several interactive factors that impact the spatial characteristics of the studied area. The landforms are highly differentiated in elevation, varying from 4000 meters on the upper Ighil Mgoun summits to approximately 1200 meters in the southern parts of the Atlas Mountain chain. A great geological and structural diversity was generated by several tectonic episodes, in particular during the Tertiary geological era. The climate type is arid to subarid in most parts of the region. The annual precipitation varies from less than 100 millimeters in the desert limits (south) to 500 millimeters around the Atlasic summits (north).

Water stress is seriously pressing everywhere. In several villages where traditional agriculture is still practiced, inhabitants tend to prefer emigration because of the lack of water for their farming activities and their derisory returns. The urban centers (Errachidia, Tineghir, Zagora, and Boumalne – Dades, for example) are, paradoxically, growing. They generate new needs in services and infrastructures. Even the public authorities are investing to satisfy these needs, though realized projects remain below the population's expectations. The new public and private investments are still unable to reduce social and spatial inequalities, emigration and the environmental crises observed in several rural and suburban areas. In this context, we consider that the recent changes in land use have serious impacts on society, landscapes and the environment. They have to be studied to find alternatives for the best future and the sustainable local development of oases.

2.2. Materials and methodology

In this study, two complementary research methods are adopted: the spatial approach and the factor analysis of data. The first approach aims to identify the landscape's biophysical and socio-economic units

Fig. 2. Photographs illustrating traditional land-use types in the upper Daes valley. Farming is balanced with water resources using small, irrigated parcels.
Source: authors, 2021.

based on data collected from fieldwork, topographic maps, aerial photographs, and satellite images.

In the Dades oasis, we used aerial photographs at 1:40,000 scale taken in August 1996 (ACFCC, Zone 3). They are compared with satellite images illustrating landscape changes during the last two decades (2000–2020). The aerial photographs covering the Ziz valley are at a similar scale and were taken on September 4th, 1973 (ACFCC, ref. ST73). But we also used other more recent aerial photographs at 1:20,000 scale taken on February 14th, 1987. The comparison between aerial photographs and satellite images was significant in terms of the changes identified. Google Earth images were used to visualize the present-day situation in oases. A GIS database of land types was developed at 1:100,000 scale. The topographic impacts were generated using ArcGIS software.

Data collected during six field visits between 2016 and 2019 were exploited. Semi-structured interviews with representative actors (mainly

farmers) were conducted. Qualitative and historic data were collected from 38 interviews in significant homogeneous sectors where approximately 5% of the residents were contacted in selected cases. These cases were chosen for their significance in illustrating the differences between the downstream, median and upstream sectors of the studied oases. Each interview is designed in respect of surveying standards (Fowler, 1995; Jong et al., 2017) to gather first-hand useful information on recent change indicators of land use and environment in oases.

The factor analysis of quantitative data issued from the last General Population and Habitat Census (RGPH, 2014) was adopted to apprehend data structures and correlations. Its main objective was to produce useful information to compare the contrasting areas and understand the oases' change dynamics, specificities and trends. As argued by Truong (2021), multivariate analysis is useful for classifying areas according to their level of sustainable development. The variables' correlation is analyzed based on a reduced number of latent factors that may be interpreted to explain the specific inherent data structures. Using the IBM SPSS statistics program, version 21, data on 44 rural communes were analyzed. Based on their socio-economic characteristics, these communes are sampled among rural communes that represent typical land use. In each commune, the socio-economic variables inherent to the population activities are used to apprehend similarities and provide pertinent indicators to explore their significance in terms of land use, environmental impacts and change.

As previously confirmed by Luo et al. (2008) and King & Thomas (2014), combined approaches to land-use parameters are important because they adopt indicators of environmental change. They permit sound comparisons of variables in order to characterize landscape units and identify the modern-versus-traditional change dynamics. In this research, each data attribute used in the factor analysis is chosen due to its illustrative signifying of temporal and spatial changes of oases, their aspects, factors, and processes. The self traditional farming (AGSYPEC) indicates the importance of traditional agricultural activities in the oases and its spatial change. The number of qualified workers (OUVMANQUALI) reveals latent factors of land use and their potential impacts on the rural economy. The initial familial farming that rarely engages wage and salary workers is shifting in several sites. We used other attributes that are significant to apprehend the socio-economic and land-use changes, such as the employment importance in private enterprise activities other than in agriculture (EMPLOY), technicians and intermediate professions (TECHPI), craftsmen, and qualified workers in services (ARTIOUVQUALI), foresters and forest activities workers (EXPAGRIPECH) and public managers or senior executives of liberal professions (MElHDCEC). We are also interested in educators, health and social action employees (ADMPUBLIEDU) to apprehend factors of intellectual and human development and its potential impact on land use. Finally, we used the attribute of building (CONSTRUC) considering its links with habitat, which in certain circumstances are strong drivers of change with direct consequences

Table 1. List of data attributes used in factor analysis

Attributes	Description
AGSYPEC	Self traditional farmers
OUVMANQUALI	Workers in agriculture (qualified and unqualified)
EMPLOY	Employees (in private entreprises)
TECHPI	Technicians and intermediate professions
ARTIOUVQUALI	Craftsmen and qualified workers (excluding in agriculture)
EXPAGRIPECH	Foresters and related forest activities
CONSTRUC	Workers in building trades
MElHDCEC	Managers, members of the legislature, local elected representatives, hierarchical officials of the public and private service, directors and executives of companies, senior executives and members of the liberal professions
ADMPUBLIEDU	Educators, health and social action employees

Source: own elaboration

on the environment. These attributes are spatially interpreted in the light of landscapes' realities. Nine attributes were adopted in the factor analysis (Table 1).

The potential impacts of these drivers are apprehended considering their consumption of resources (mainly water and soil) and their impact on the environment.

The validity of sampling was tested using the statistical Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests. The final results were reviewed considering the realities of the field in each rural commune.

3. Results and findings

3.1. Factor analysis of the data

The 44 studied communes tend to form clearly distinct groups in which the dominant land use revealed by the socio-economic variables' correlations reflect typical (somehow homogeneous) areas, giving evidence to discuss the evolution of environmental equilibrium. The correlation matrix indicates that the variables are differently correlated, as some correlations are stronger than others (Table 2).

The KMO index indicates that the correlations between the items are qualitatively good. Barlett's sphericity test is very significant (p=0.000) (Table 3).

As the correlations are not all equal to zero, the analysis was continued. We calculate the contribution of the data attributes to the principal components to explore similarities between the studied rural communes, basing on these socio-economic variables.

We note that the two first factors (components) have an eigenvalue greater than 1. (According to Kaiser's rule, only components with eigenvalues greater than 1 are retained.) We therefore consider them for analysis and interpretation. The first factor explains 60% of the total variance of the nine variables used in the analysis. Combined, the first and the second factors explain 79% of the variance.

The eigenvalue graph (Fig. 2) that illustrates where the Cattell elbow rupture is located, shows a change after the second factor.

The results confirm the findings in Table 4. We therefore retain the two factors 1 and 2 that will be interpreted to explain the data structure in the area. To interpret these two factors, we investigate the

Table 2. Correlation matrix

	MElHDCEC	TECHPI	EMPLOY	EXPAGRIPECH	ARTIOUVQUALI	OUVMANQUALI	AGSYPEC	CONSTRUC	ADMPUBLIEDU
MElHDCEC	1.000								
TECHPI	.607	1.000							
EMPLOY	.301	.479	1.000						
EXPAGRIPECH	-.633	-.451	-.504	1.000					
ARTIOUVQUALI	.205	-.014	.366	-.549	1.000				
OUVMANQUALI	-.489	-.344	-.520	.784	-.755	1.000			
AGSYPEC	-.576	-.410	-.542	.919	-.709	.965	1.000		
CONSTRUC	.429	.161	.149	-.718	.597	-.807	-.816	1.000	
ADMPUBLIEDU	.785	.772	.491	-.603	.225	-.543	-.599	.394	1.000

Source: own elaboration

Table 3. Kaiser–Meyer–Olkin (KMO) and Bartlett tests

Kaiser–Meyer–Olkinmeasure of sampling Bartlett's test of sphericity		0,737
Bartlett's test of sphericity	Approx. Chi-square	591.345
	Dg	36
	Sig Bartlett	.000

Source: own elaboration

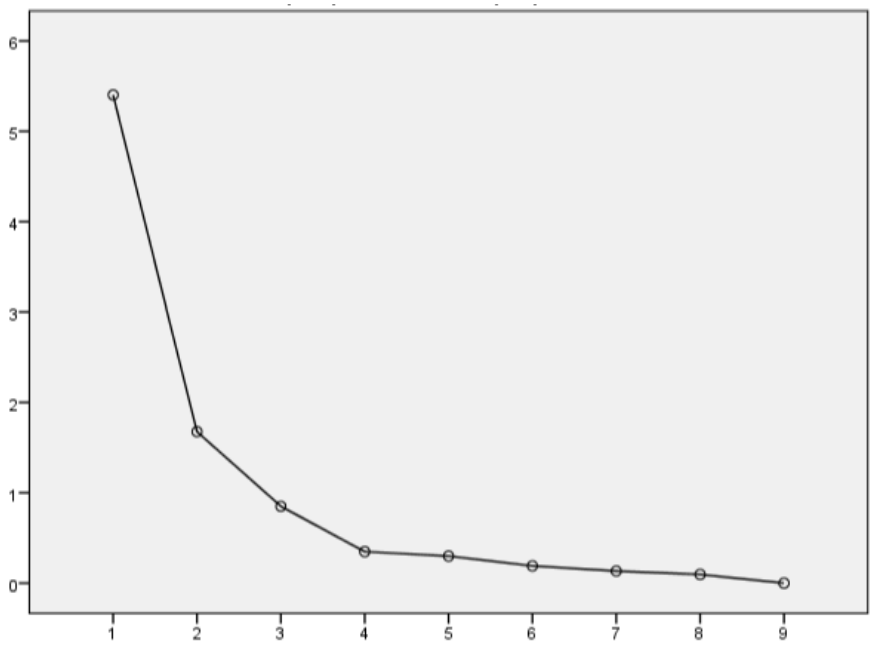

Fig. 3. Eigenvalue graph illustrating the Principal Components
Source: authors, 2021.

combination of variables that are most associated with each of the significant factors in a rotational matrix. The results are presented in Table 5.

The main components are interpreted by searching the elements that are most strongly correlated with each component. The most distant from 0 in their positive or negative direction are of great explicatory value. A correlation value greater than 0.5 is considered important. In factor 1, the well-represented variables are OUVMANQUALI, AGSYPEC, ARTIOUVQUALI, CONSTRUC, EXPAGRIPECH, whose total correlations exceed 70%. This factor reflects qualified and unqualified employment in sectors of agriculture, crafts, and building. Factor 2 is in the second position and represents the variables TECHPI, ADMPUBLIEDU, MEIHDCEC, EMPLOY that assemble persons working in the public administration, management, and services. Strong correlations are also observed in this factor (Fig. 4).

Figure 4 shows clearly the composition of the factors. Each point represents a variable on the diagram. On axis 1, the variables related to the building trades as well as those of traditional agriculture evolve in the opposite direction. These variables are not correlated with the administrative and management professions that make up axis 2.

Table 4. Total variance explained by each factor

Component	Initial eigenvalues			Extraction sums of squared loading		
	Total	% of variance	% cumulative	Total	% variance	% cumulative
1	5.404	60.040	60.040	3.865	42.941	42.941
2	1.676	18.624	78.664	3.215	35.723	78.664
3	.850	9.450	88.114			
4	.349	3.873	91.987			
5	.300	3.329	95.316			
6	.191	2.123	97.439			
7	.134	1.486	98.925			
8	.097	1.073	99.998			
9	.000	.002	100.000			
Extraction method: Principal Component Analysis						

Source: own elaboration

The projection of the statistical units in the factorial plan Dim1-Dim2, shows four groups in the studied communes. Each is composed of communes that approximately share the same socio-economic characteristics and similar land use, as shown in Fig 5. These four groups are:

Group 1: Similar specificities in terms of position at the high mountain depressions favoring the conservation of traditional agricultural and forestry activities that consume limited water resources. Somewhat of an environmental equilibrium is still maintained. The traditional resource management in the area remains environmentally decent in most cases.

Group 2: Communes also distinguished by their geographic position in the mountains, but more administrative employees are observed in this group.

Group 3: Communes geographically located at the piedmont, in the interface zone between the mountain and the external plateaus in the south. Traditional agriculture is progressively shifting. The dominant activities are building, public administration, education, health and social action. Other activities related to institutions' members, local elected representatives, hierarchical public service officials, company directors and executives, senior executives and members of the liberal professions, technicians, intermediate professions,

Table 5. Rotated component matrix

	Component	
	1	2
OUVMANQUALI	-.893	-.359
AGSYPEC	-.878	-.451
ARTIOUVQUALI	.877	-.034
CONSTRUC	.855	.167
EXPAGRIPECH	-.739	-.530
TECHPI	-.014	.918
ADMPUBLIEDU	.250	.895
MEIHDCEC	.277	.791
EMPLOY	.332	.550

Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; Rotation converged in three (3) iterations

Source: own elaboration

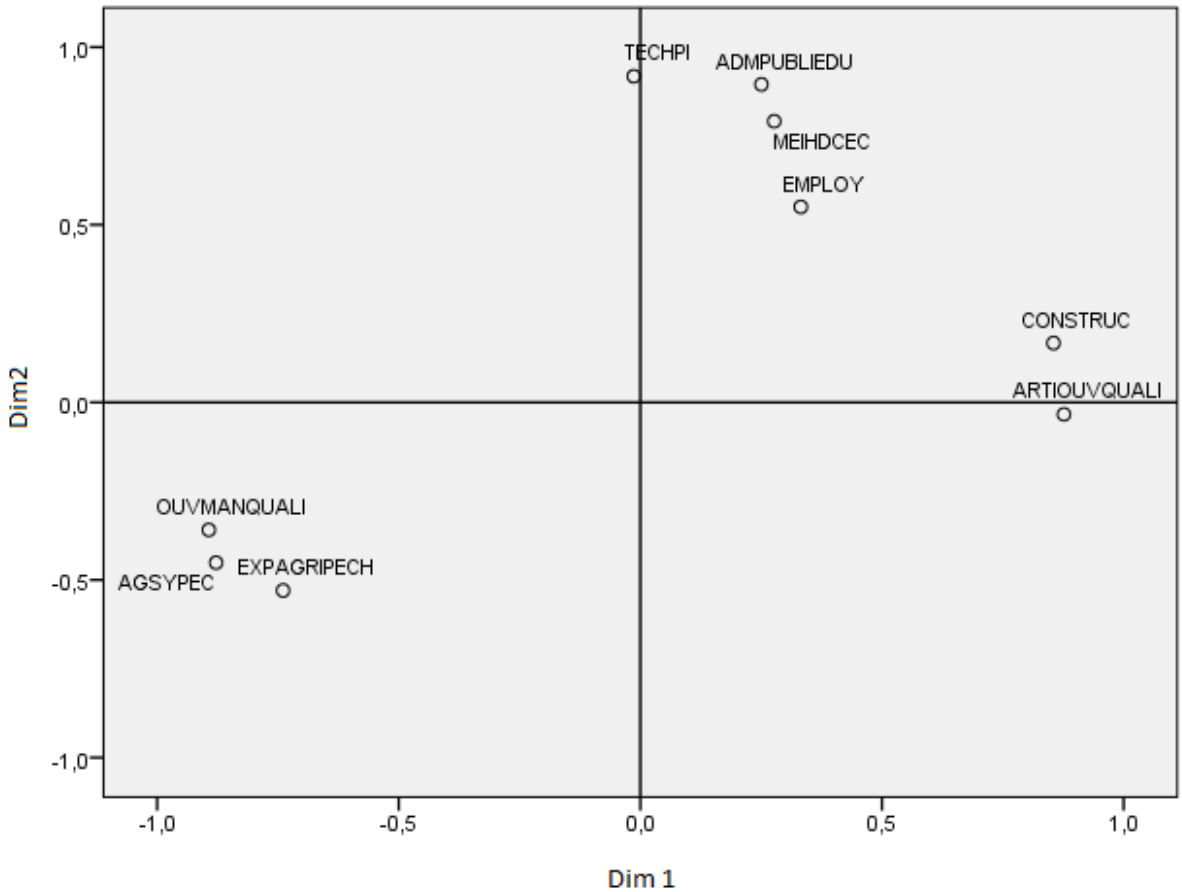

Fig. 4. Projection of variables on the factorial plane
Source: own elaboration

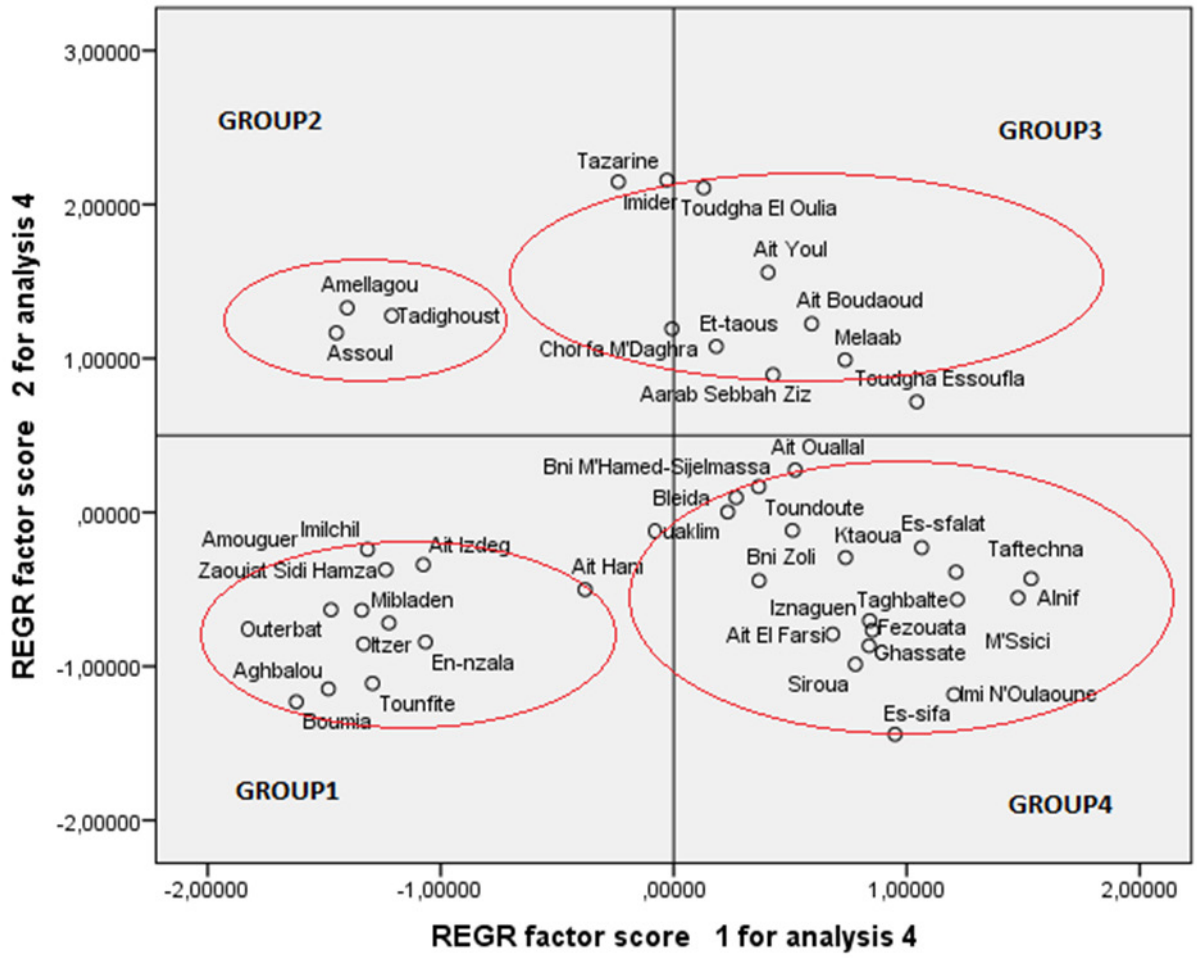

Fig. 5. Projection of statistical units (rural communes) on the factorial plane
Source: own elaboration

and employees are also important in this group. In Fig. 4, we note the exception of Tazzarine that is observed among the communes of this group even though it is geographically far to the south. But its important proportion of managers, administration staff and migrants may explain this position as this criterion brings it close to group 3.

Group 4: Communes downstream, where traditional agriculture is in crisis due to the climatic conditions and the socio-economic and demographic parameters. As in group 3, the dominant characteristics of activities are linked to the building sector. A strong presence of craftsmen and skilled crafts workers is also observed. Paradoxically, in several communes of this group, several modern farms appear that are irrigated by pumped underground water.

The identification of the four groups of communes by factor analysis converges with the results of prior scientific studies, which have recognized contrasting socio-economic areas along the Mgoun, Dades, Todgha, and Ziz valleys (Bencherifa and Popp, 1992). Our study results give evidence of different environmental impacts of land use in each sector.

3.2. Changes and upheavals in the oases' economies and environments

As observed in the field, the groups of rural communes obtained from the factor analysis show the influencing processes of modernity in land use and landscapes in the selected communes. Each group's change depends on the geographic location and the intrinsic or exogenous factors. These factors are differently impacting land use and the inherited environmental equilibrium.

The fieldwork results confirm the fact that the environmental impacts of new farming techniques, building and new economic activities have caused profound landscape changes over the past four

decades. Agricultural irrigation is facing water scarcity in communes of groups 3 and 4 in Fig. 5.

The increasing demand for drinking water in the fastest-growing agglomerations and the lack of sanitation networks are mentioned as recent problems by 40% of the interviewed persons in Boumalne Dades and Tinghir. This refers to the recent impacts that urban extension, international migration income, communication technologies and the intrusion of new farming practices that consume resources have had on the local economy. Such problems are still unnoticed in the upper parts of the oases, where traditional rurality still dominates.

In most communes, pressure on resources is observed, but in communes of group 4 mentioned above the environmental stress is very high. For several decades, traditional agriculture has been decreasing as other economic activities have been developing. Demography, socio-economic factors, modern techniques in water pumping, and water consumption by domestic equipment are major factors driving change. Locally, new modern agriculture has grown outside the traditional oases, as observed at the vicinity of Zagora (watermelon farms) or "*Mejhoul*" date farms recently created between Errachidia and Boudenib (Fig. 6).

Between Boudenib and Errachidia, the underground water from the Cretaceous aquifer is pumped by modern techniques to irrigate these farms. This type of agriculture is developing while traditional rangelands decrease. Thus, large modern farms have appeared on dozens of hectares in many pre-Saharan sites, outside traditional oases. The farms are irrigated by groundwater pumping and exploited using modern farming techniques that, in some cases, do not take into account ecosystem vulnerability, scarcity of water resources or sustainable ecological balances. Thirty percent of interviewed oasis residents declare that the crisis is deeper and say "anarchy" and the modern exploitation of resources are dominating.

New farming productions irrigated by pumped underground water are also developing in the

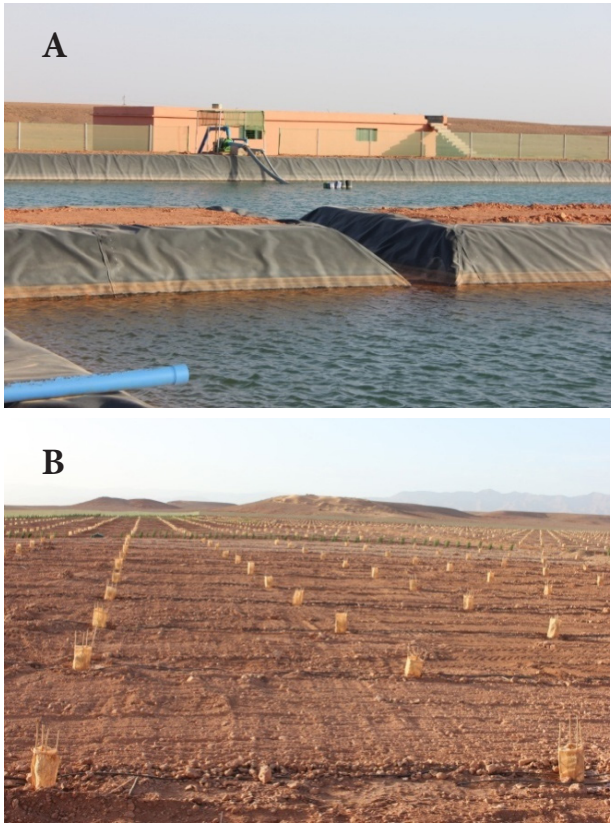

Fig. 6. Photographs illustrating new capitalist-type farms on the Hamada of Meski south of Errachidia: A – Pumping station from the cretaceous aquifer in Errachidia region; B – B. New young palm farms of "Mejhoul" irrigated by pumped underground water
Source: Laaouane, 2017

Fig. 7. New private modern agricultural investments near Zagora in Draa, A – Underground water pumping station for the irrigation of commercial crops (watermelon, henna, etc.); B – Modern agricultural irrigation in new farms of the arid land between Tazarine and Zagora
Source: Authors, 2019

desert in the Zagora province (Fig. 7). Watermelon production is a significant example. In 2008, it was non-existent in the area, but it rapidly developed to cover 725 hectares in 2012 and 2,500 ha in 2014 (ORADO, 2014).

The illiterate population in rural areas remains dominant in most studied rural agglomerations. The results of the *General Population and Habitat Census* of 2014, show that the illiterate population varies between 27 to 52% in oasis villages. The rate of Internet use by the population is almost 22% throughout all the communes under study.

4. Discussion and perspectives

Mutations in society, economy and landscapes are creating contrasted units in oases. Innovations are centered in the south but they are rapidly and progressively extending to the north following a "pseudo-contagious" diffusion pattern previously framed by innovation diffusion theory (Blaikie, 1973; Rogers, 1983). We expect greater consumption of water to meet modern agricultural irrigation and urban drinking-water needs in the future. Oases will experience more risks of desertification. However, the traditional rurality is still impressive in the uplands, where subsistence agriculture is often practiced.

As documented in Tunisia (Rodríguez-Caballero et al., 2017), so too in the Moroccan oases, the expansion of irrigated oases is becoming spectacular. The phenomenon appeared two decades ago (Daoud, 2001) and expansion is currently accelerating. Recently, new agricultural investments have been appearing in managed sectors irrigated by pumped underground water. Many interviewees (70%) agree that such actions are risky and may destroy the achieved environmental balance. The new sectors of modern farming exploitation (desert farms) are often managed by investors, who neglect the conservative rules of the millennial Intellectual Capital accumulated by the oasis communities. The environmental conservation perspectives in oases are therefore critical under such a development model. Practices and techniques that do not respect the environment engender irreversible and unintentional destruction of interactive local ecological systems, as studied in similar contexts in Central Asia (Hu et al., 2020). The conservational and intangible capital use of resources in local development are marginalized, despite their important role in human adaptation to arid environments and in developing social risk strategies (Blanco & Carrière, 2016). Such strategies are factors of land degradation and desertification (Seif-Ennasr et al., 2016). The three main observed types of change are:

- the expansion of oases outside the traditional irrigated valleys. This change is more evident downstream in most oases.
- the modernization of oases is observed mainly in groups 3 and 4 above. It is evident in building activities and outcomes, farming techniques, and socio-economic characteristics. This change is strongly affecting the oases downstream and is progressively extending to middle (central) sectors inside the mountain domain. Such phenomena are still very rare upstream.
- the spatial, socio-economic, and environmental contrasts in different oases are growing. These changes are noticeable due to the demographic increase, the urban development and modernization modern practices and other change drivers. A population of approximately 1,635,008 inhabitants in 2014 (2% of the national population) spans all of the oases in the region.

The use of intangible capital to develop regions is very important (Chauffour, 2017). But it is weakened by the ongoing mutations in the oases. The education level of the rural population is commonly low, and its Intellectual Capital is deeply altered by modernity, technology and general misuse of resources.

Despite the modern technological growth observed in this area, it has not greatly improved the average cumulative Intellectual Capital of the population because their low level of education prevents them from taking advantage of these facilities in terms of choosing pertinent land use for sustainable development. Illiteracy is pervasive in rural areas. Thirty-two percent of the interviewees confirm that the Intellectual Capital of residents has progressively declined, despite the technological growth of communication tools and the modern localized investments in farming outside the extension of oases. It is worth mentioning that inherited ancestral environmental awareness is weakening and the oases are facing the critical environmental effects of modern land use in, for example, habitat projects, agriculture, irrigation techniques and tourism.

The present research findings confirm that the new land-use types and modern technologies locally introduced in oases, the extension of agglomerations, and new agricultural irrigation

techniques based on pumping in selected sites are often ignoring sustainability paradigms. Most farmers have low adaptive capacities and a low level of education. The inherited dynamic environmental equilibrium of oases is under stress and should be considered for prospective rural planning and sustainable development.

The migrants and emerging elites of oasis tourism are other new impacting facts. As tourism creates new jobs and job profiles such as caravan organizer, transporter, activity leader, and heritage interpreter, it is a major driver of sociocultural change in oases.

This study's outcomes show that the current oasis environment, mainly downstream, has dramatically changed due to modern mutations in economy, society, quality of life, building, urban areas, services, and some modern investments. The new oasis context is characterized by progressive technological growth that should be sustainability oriented. The marginal communities disadvantage model discussed by Hakikur (2006) is confirmed. The low level of education we noted among peasants aged over 15 years and the pervasive illiteracy in rural areas is a constraint that does not favor innovation in terms of conservational alternatives regarding natural resources. The change is commonly perceived as a stress by the population (Fig. 8).

The landscape, socio-economic and environmental changes are observed everywhere but they are slow in the upstream zones. The Mgoun upper valleys are less affected by some new activities such as building and services, but they are changing due to climatic change and deforestation. The median sectors of the studied oases, especially in the Todgha and Ziz valleys, are progressively influenced by modern infrastructures and new economic activities (mainly tourism), but traditional agriculture is still active. Anthropic action and strong change processes are observed downstream.

Considering these very contrasting characteristics of oases, the palliative measures must be specific to each sector. They can be preventive, corrective or mitigating, according to local needs in each case.

Development could be made in accordance with the requirements of sustainable development based on the knowledge economy, the proper use of technology, and the conservational valuing of resources. The natural resources, land use and landscape have to be managed by awareness to avoid the tragedy of the commons theorized by Hardin (1968) and Bezin and Gregory (2019).

Urgent preventive and corrective measures are necessary to reverse the observed harmful trends and engage new strategic actions to seize the niches of potential development that fit with local culture and local vocations of oases, without disturbing the environmental equilibrium. These were basic elements that contributed to perpetuating harmony in landscapes and the balanced renewal of resources for centuries. It would be difficult to restore the situation and establish a new order without very intense public intervention and the commitment of local actors (governmental and private). The disappearance of traditional solidarity structures and the increased domination of private-profit transactions are new problematic issues that should be addressed by the government and other concerned actors. The roles and responsibilities of actors should be redefined considering ways of

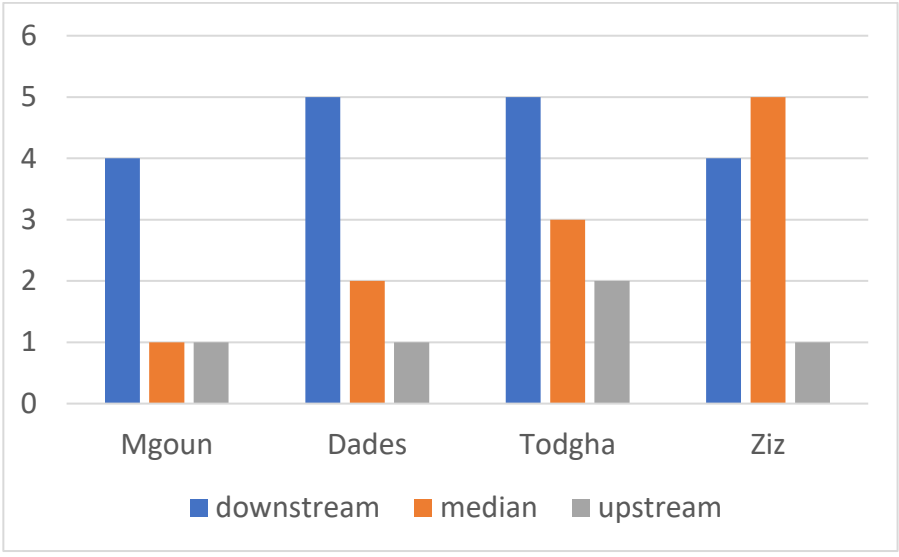

Fig. 8. Perceived change in different sectors of the studied oases
Source: Authors,

strengthening the environmental balances and the sustainability of implemented development.

5. Conclusions and recommendations

The study reveals important land-use changes underway in several parts of the studied oases. Four different groups were identified using a factor analysis of their socio-economic characteristics. The environmental equilibrium and resources are under stress, mainly downstream and at the piedmonts, where modern activities and building extension are taking place. Despite the recent local modernizations in farming, building and doing business, the negative trends in the oasis environment are problematic.

Recently, several actors have been neglecting the ecological fundamentals that have ensured the sustainability of these landscapes that are full of cultures and traditional civilization. The new business styles, visions and aspirations of the new generations are different from ancestral practices and seem to have negative impacts on sustainability and the environmental equilibrium. The unintentional destruction in interactive local ecological systems is very complex to manage and may be irreversible in some cases.

Among the practical implications of the study, we underline the hazardous types of land use downstream. To address the changes in oases, no radical, immediate solutions exist, but strategies for the future could be developed in an integrative global vision, using motivations, restrictive or coercive actions and more participation by concerned actors in the conservation and sustainable development of the oases.

Trends of modernization within the oases must be framed in the future by a sustainability perspective in which economic and technologic development and human activities will operate in harmony with issues of environmental equilibrium and heritage protection.

Finally, it is worth mentioning that some limitations to the change study in oases were noted because the changing processes involve multiple factors and are complex. Given the data at our disposal, the regional scale was adopted in the study, although we are confident that a more detailed scale (provincial or local) and a larger sample may be pertinent to study the socio-economic parameters. Prospective research may be done to overcome these limitations and explain the theoretical and practical implications of the change in oases and their identified spatial contrasts.

Several recommendations are underlined in the study: (1) The adopted development models of oases and drylands need to be rethought, in order to elaborate new actions that respect local specificities. (2) There is an important role for anticipating environmental risks in major new farming projects, due to their vulnerable context. Anticipation is needed to balance the ongoing change processes in oases according to the fundamentals of environmental equilibrium. (3). Urgent priority actions are needed to rehabilitate the disturbed ecosystems and avoid environmental ruptures. 4) Based on the environmental risk signals described in this study, further research into the development sustainability perspectives in oases remain pertinent in the future.

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