

Eco-sustainability awareness, intellectual capital and education in the Moroccan Oases

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Abstract: This study apprehends awareness of eco-sustainability and environmental protection as influenced by intellectual capital in drylands. We focus on the case of Moroccan Oases. The intellectual capital components are changing. They differently affect sustainability and local development. The study identified these deep changes and their spatiality in oases. Challenges and suggested perspectives are discussed.

The adopted methodology in the study focuses on fieldwork, interviews (2017-2024) and analyzing data of the official Moroccan census of population and habitat (2014; 2024). Semi-structured interviews were adopted in data collection. In each oasis and selected rural communes, several variables were considered to apprehend the intellectual capital based on the cultural, economic, social and environmental mutations.

The findings underline a decrease of the local knowledge and traditional practices in specific sites, while the oases' modernity and new business practices increase in others. Their impact on natural resources and environment are risky. The spatially contrasted cultural and economic changes appear comparing the traditional sectors of oases and the developed modern irrigated farms recently created. These are exuberantly water consuming and often located downstream. The intellectual capital characteristics are impacting the environmental equilibrium as traditional sectors are generally conservative, and modern areas abuse in resources consuming.

A huge need for sensitive education and further consideration of the cumulative Intellectual Capital including its traditional and selected modern components, is important to re-orient action to sustainable entrepreneurship and environment protection. It is a priority to re-consider education and intellectual capital to develop the population's environmental conservatory

1. Introduction

Intellectual capital, Climate and social mutations were among key factors of change in the Near East and North African oases during centuries (Clarke et al., 2016). They favored ancient civilizations' development in semi-arid lands. Trans-Saharan trade and adapted traditional entrepreneurship activities developed in oases, while environmental equilibrium had been saved. Local ecological knowledge that serves sustainability had been shared (Blanco and Carrière, 2016). Ancient cities and historic business centers such as Tombouctou and Sijilmasa increase their visible cultural influence, without

major disturbance of environment. However, during the ninetieth and twentieth centuries, further evolutions of this intellectual capital occur in most cases. The change was high following the colonial period, intrusions of modern, capitalistic economic models and the adoption of new lifestyles and resources' consumption in oases. Modern entrepreneurship initiatives appear in tourism, agriculture, quarrying, building and other sectors. Most of them neglect the aptitudes of natural resources' renewal and the endogenous knowledge. They threaten the balanced environmental equilibrium acquired for centuries. Faced with technological growth in the oases, a strong loss of reasoned environmental adaptation skills of the actors is observed, because the developed Intellectual Capital, influenced by external inputs, tends to neglect the fundamental ecological equilibrium, which had ensured sustainability of cultural landscapes. Current business models, visions and aspirations of the new generations become different from the ancestral practices and thus, on several oases, generate quite a negative impact on the environment. Such novelties in the Intellectual Capital comprise the environmental equilibrium as their impact in terms of preserving resources is not guaranteed.

The intellectual Capital and resources' use are emerging as factors of sustainable development and apprehension of environmental equilibrium (Giustina et al., 2020). They can influence the creation of activities that generate wealth, jobs and sustainability. They strengthen the local systems' ability to face new challenges of development, vulnerability and environmental stability, especially in developing countries (Biker et al. 2004). Their importance is recognized by international economic and financial organizations (World Bank, 2006; OCDE, 2013). Intellectual Capital includes the accumulation of ideas and wealth owned individuals and communities, and their modes to manage and exploit space and resources. It encompasses the knowledge, skills and intellectual genius developed to manage complex situations and do business. It therefore includes endogenous components and heritages, issued from local cultures, practices and skills, and exogenous components, introduced by the business system, exchange with the external environment, socio-economic changes and the influence of new techniques. New technologies of information and communication contribute to Intellectual Capital development as they affect the ecosystems, business environment and entrepreneurship motivation (Akdim, 2020; Do, 2022). The influence of formal and informal institutions on foreign investment has been confirmed in the literature (Holmes et al., 2012). The role of culture and education determines factors of the organization and influencing innovation in the case of enterprise and landscape. Oases are cultural landscapes known as built systems of human civilization over the several centuries

The inherited local intellectual capital favored individual and collective entrepreneurship initiatives that value the ancestral innovations developed in respect of local environment. In the Moroccan oases, a typical symbiosis between the Intellectual Capital and environmental knowledge was recognized by several authors (Blaikie, 1973; Bencherifa et Popp, 1992; Ait Hamza, 1999).

Within the present – day context of oases' environment and their frightened equilibrium, the research questions of this study apprehend change factors and challenges in IC that impact environmental status of oases.

As the technical and modern investments are also among the IC and may negatively affect the environment when misused, they provide comparative cases to study their impact on environment and sustainability development. Data mapping of Intellectual capital and education tools are suitable tools to encourage sustainable entrepreneurship, suitable practices to strengthen the intergenerational Intellectual Capital and improve it by modern and technical contributions to conserve the environment. The case study in this article is the Southeastern Morocco administratively framed by the Draa – Tafilalet Region (Fig.1).

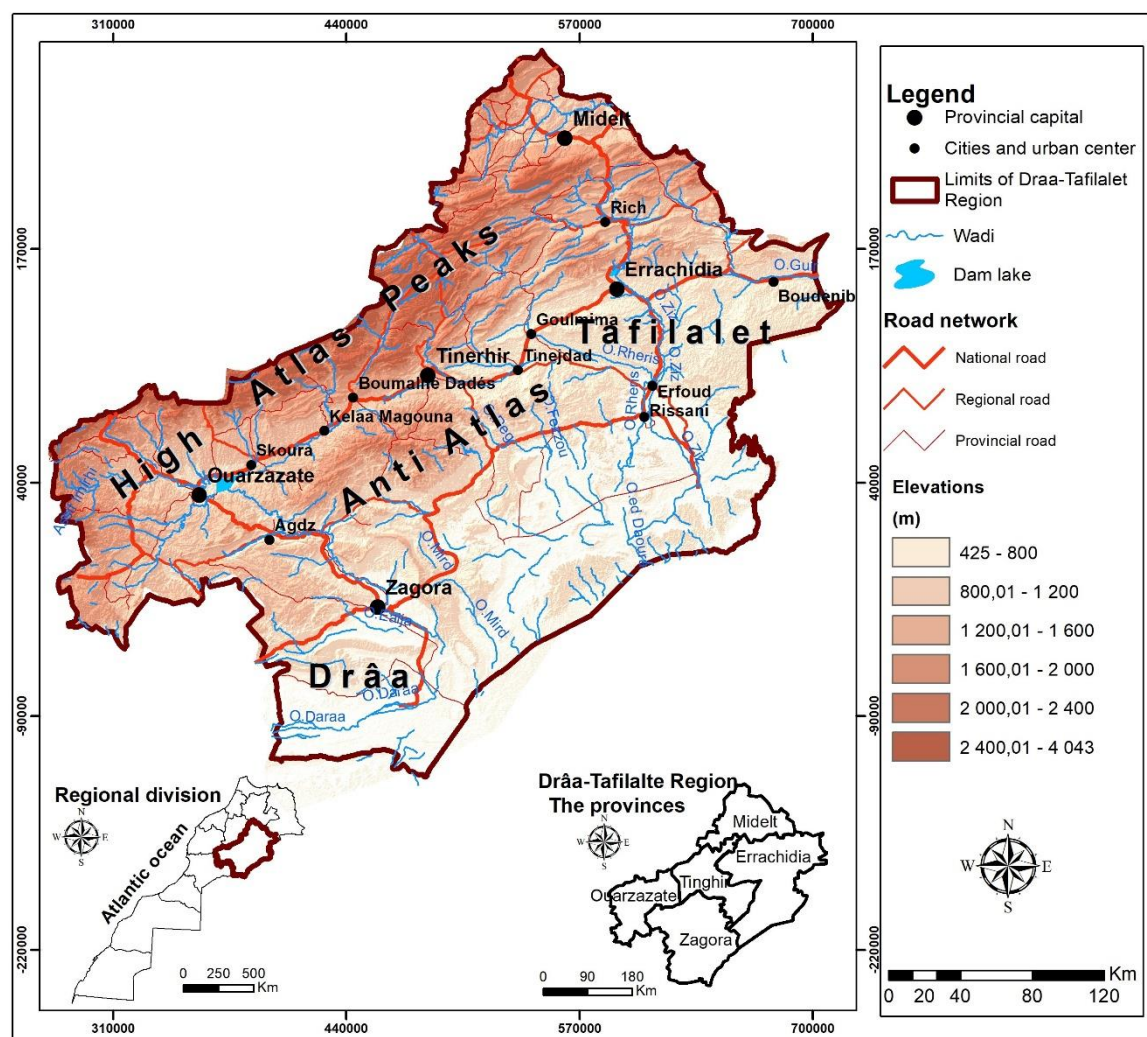


Figure 1. The studied rural communes of the Draa - Tafilalet region (Morocco).

Despite the growth of emerging urban centers such as the administrative centers and towns (Errachidia, Ouarzazate, Tinghir, Zagora, etc.), the population is generally rural in this area. The rural population is mainly concentrated in villages *douars* along mountain valleys and oases. Traditional economy is still maintained but several rural communes are experiencing modern activities (Aafir, 2006; Montasser, 1985; El Faskaoui, 1996). Strong intellectual capital changes are presently operating in the region and have serious environmental impacts. They are induced by the ongoing ways of resources' consumption and landscape's uses. As noted in other oases all over the world (Carpentier and Gana 2017), these mutations may have destructive consequences on the area's future.

This article apprehends links between eco-sustainability, Intellectual Capital and education. Their spatial, temporal, sociodemographic and cultural dimensions are fundamental issues to enhance awareness to present and future environmental sustainability in oases. Its main objectives are:

- To apprehend the generations' differences in understanding the environmental risks and what are their eco-sustainability perceptions?
- To identify key elements of a strategic plan of eco-sustainability awareness, mainly in valuing the intellectual capital and education.

2. Conceptual framework, background and research questions

2.1. Awareness and education

The term "awareness" was differently used in literature. It was used in psychology, philosophy, education, and communication to design human consciousness about an object, generally risky. Baars (1988) and Chalmers (1996), developed a cognitive theory of consciousness by using contrastive analyses with unconsciousness to understand the conscious experience. He underlies the major role of the context in modulating human behavior to face vital questions. Block (1995) suggested some basic elements of consciousness as a function of reasoning and initiating rational control of a phenomena, including therefore the cognitive executive system. In this case, environmental decisions and adaptations are commonly developed based on abilities that humans develop to resolve the environmental emerging problems. Awareness may be apprehended at the public level including government development politics, laws and strategies or at the Individual level as affected by education, beliefs, emotion, cognitive and cultural heritage and daily personal behaviors. It was adopted as a pertinent concept to produce spatial data (Thellufsen et al., 2009). Filho et al. (2024) adopted the awareness paradigm in circular economy development. Their findings illustrate the paramount importance of local intellectual capital, personal values, beliefs, and positive evaluations of sustainability outcomes in facing the external environmental pressures. Che and Yang (2024) confirmed the usefulness of the human awareness in driving sustainable cities. In the oases' domain, the intellectual capital transmitted as heritage, favors awareness in human adaptations to natural and ecological hazards. A changing vision of present-day education should include such environmental awareness and promote sound wise heritage in resource management and environmental systems' restoration. Formal and informal sensitive education will gain in integrating the paradigms of intellectual capital and eco-sustainability in developing humans' awareness.

2.2. Intellectual Capital and eco-sustainability

Intellectual Capital (IC) has been introduced as a research topic since the nineties of the last century, particularly in the business and management sciences (Klein, 1998). It consists of four components: human capital, structural capital, customer capital and innovation capital (Lacroix et Zambon, 2002). From an organizational point of view, Intellectual Capital becomes one of the three main components of business organization and management, in addition to physical or material capital and financial capital. It includes knowledge, know-how and practices adopted by the organization's actors. Its use in business has been considered important on the creation of value (Bueno et al., 2014; Rusu-Tanas, 2015). It brings intelligence and wisdom together, allowing actors, especially the top managers of the companies, to make strategic choices. These choices ensure efficiency, competition and sustainable growth of their projects. Interestingly, there has been a noticed impact of the IC on regions and enterprises' competitiveness (Biker et al., 2004). Besides, Yusliza (2020) studied the relationship between green

Intellectual Capital and sustainable performance, and her findings reveal that indeed the IC positively influenced economic, environmental and social performance.

In a recent literature review on Sustainable development, IC and technology policies, Giustina et al. (2020) argue that major contributions in this topic focus on the IC role in Sustainable development in Private Sector and illustrates its importance for Sustainable Regional Development in the Knowledge Economy and its impact on the development of the Public Sector and organizations.

Moreover, IC has recently gained consideration in environmental studies and has been recognized as a factor of sustainable development as it contributes to strengthening ecological balances (Seitkazieva et al., 2018; Aboelmaged and Gharib, 2019, Yussli et al., 2020). The World Bank considers the IC among the factors of development in emerging economies countries, where intangible capital represents a potential source of the nation's wealth (World Bank, 2006; OCDE, 2013). It has been recommended to investigate this perspective, especially in Morocco (Chauffour 2017).

2.3. Background of the Intellectual capital use to development's implementation in the Moroccan oases

The IC is considered one of the assets for the rehabilitation and development of oases (Ahrabous et al., 2023). They represent millenary heritage areas. The accumulated intergenerational IC of the oases allowed them successful adaptation to the environmental constraints during several centuries, even natural resources are scarce, and their context is restrictive and often under stress. The resources were exploited according to procedures and practices adapted to the context. Currently, the acquired environmental balances in oases are suffering, due to the evident climate change and because the changes in IC are bringing about other modes of management and exploitation of resources influenced by other considerations that are distant from the conservative concepts of resources, which were the founders of the Oasis civilization (Akdim et al., 2023). Economic and technologic modernization does not, in all situations, support environmental equilibrium.

The interactions between the IC and the oases environment" are intense. The natural capital (in stock), mainly made up of soils, plant cover and water resources, is declining because it is gradually threatened by human anthropic pressure. The injected financial capital is fluid and greatly changing, depending on circumstances (public investment, contribution of emigration income for example) and the oases' IC (endogenous inherited and recently developed following exogenous factors) are presently changing, affecting the local environmental and socio-economic balances. The spatial change of IC along the Atlas Mountain from the upper summits to the lower valleys and outside the mountain is considerable. Modern components of IC increase in the last areas. In parallel, human pressure on resources increases, showing links between IC type and environment equilibrium. The illustrations of these links are presented and discussed in the following paragraphs. They highlight the possibilities of using them as analytical tools to understand and spatialize the environmental balances and therefore implement strategies to deal with them. Awareness-raising and education complete these tools to redirect action priorities in terms of development choices.

2.4. Study's research questions

Several questions emerge as to what extent does the IC approach reflect spatial environmental change related to modernization trends in the southern oases? What are the apparent and latent links with the resources stock and environmental equilibrium? When observing defined units, how can we explain their structuration using the farming induced practices that engender the deterioration of environmental balances? Are they

correlated to the IC change and new local practices in agriculture, building expansion, new socioeconomic activities that are more water consuming? How may awareness and education support IC as a tool of sustainable entrepreneurship and regional development in similar areas?

In the oases of Draa-Tafilalt (Morocco), we question the environmental efficiency of modern intellectual capital, including recent investments and technologies for sustainable development. Do newly introduced technologies and investment always create sustainable wealth in oasis? Although their potential local positive role in certain cases, their sustainability is conditioned by their impacts on resources, environment and space management, itself depending on cumulative Intellectual Capital, including its endogenous and inherited components. Acute questions are emerging regarding the role of the Intellectual Capital's change in marginal spaces under the ongoing climate change? What are perspectives of populations' inclusion in these areas? What significant relationship may appear between the development of Intellectual Capital (IC), the types of entrepreneurships, agriculture investments and the environmental equilibrium in oases? We assume that the components of the heritage and traditional human capital when supported by sensitive actions and education may be very important to promote sustainable entrepreneurship and strengthen the environmental balances.

3. Materials and Methods

3.1. The studied area and methods

The Southeastern Morocco extends overall territories of the Draa-Tafilalet administrative region. It includes multiple oases on the Atlasic Mountain flank and its southern piedmont. Each oasis has its own cultural and ecological specificity such as palms planting, olive trees, fig trees, etc. The oases are considered as millennial spaces of human adaptation to the constraints of the environment, notably aridity and water scarcity, but each space presents local, social, cultural and socioeconomic specificities (Akdim, 2012).

The balances inherited from millennial human adaptations to the vicissitudes of the physical environment are now very threatened. The demographic and socio-economic mutations (Tab. 1) are certainly responsible for these trends (Akdim et al., 2017, Errahmouni, 2014; Sabiri, 2020).

Table 1. Socio-economic characteristics of the pre-Saharan zone. Source: Akdim et al. (2017).

		Population			Agriculture			Breeding		
Total Pop	Rural	Rural	Analphabets	Actives	Useful agri.	Dry	Mean	Bovines	Sheep	Goats
	pop.	density	(%)	(%)	area	farming	farms	(1000)	(1000)	(1000)
	(%)	Hab/ km ²			(1000 ha)		area (ha)			
1312 130	0,68	8,56	42,1	27,1	151	51%	2,38	46,6	770,1	461,3

Change of IC during the four last decades is not spatially homogeneous compared to the upper and the lower parts of the Atlas mountain's flanks and its draining valleys (Oases). Economic, social and environmental contrasts developed. The oases

activities are different in terms of impacts and environmental balance, according to the modes of exploitation of resources, itself linked to developed local IC (technical, cultural or socioeconomic).

The study focuses on several areas where preliminary fieldwork shows contrasting characteristics evidence, as follows:

- the intensive traditional and rural activities in the upper valleys (Draa, Dades, Mgoun, Todgha, Ghris, Ziz), including in the isolated oases at the piedmont of the Saghro mountain and the southern flanks of the High Atlas. Most of them are less affected by modern modes of resources' exploitation. Emphasis was placed on studying the role of socioeconomic variables in these areas, where the cultural heritage and resources conservation techniques are prevalent. In these areas the sustainability of resources use is linked to the heritage and traditional activities still presently adopted.

- The most modernized areas where new farming investments and recent extensions of the oases are detected at the piedmont. In these areas traditional agriculture is considerably weakened and alternative activities such as trade, enterprise and other employment sectors with different consuming modes of resources are developed. The environmental equilibrium is less considered in these areas.

The rural communes representing these areas are selected for study in the Ziz, Ghris, Dades and Mgoun valleys. Near Errachidia for example, significant new extensions of the oasis are observed, presaging for their irrigation an overexploitation of the underground water. The lots granted to young farmers who carried agricultural investments or farms developed by companies and individual entrepreneurs are impacting the area. In Todgha and Dades downstream valleys, considerable modern activities are taking place with major negative environmental impacts, mainly in rural communes at the proximity of urban centers.

3.2. Surveys and fieldwork

- Semi-structured focus group were asked to fill questionnaires with open-ended questions. They are widely distributed among oasis populations from different social categories in the 44 rural municipalities studied (220 people surveyed).

- These focus groups include key informants (elderly people, representative of socio-professional categories as farmers, immigrants, shopkeepers, elected officials, hotel entrepreneurs, retired civil servants, livestock farmers).

- Interviews with key people working on large farms in Dadès, Ghris, and Haut Ziz. Given their major impact of these farms on the territorial change process. These impacts were explored through interviews with key people, such as technicians, farm workers, and company managers working with investors. Our primary criteria for selecting these people were their extensive knowledge of the key economic, social, and, above all, environmental dimensions of these farms.

To complete our understanding of the studied realities an open survey was launched on Google Forms in 2025. It reached 75 people who expressed their views on the environmental problems of the oases and their connection to the intellectual capital of the inhabitants, whether in terms of causality or solutions to the problems faced.

3.3. Used data in digital mapping and analysis

The used data is derived from four different sources: data from the census of population and housing (2014; 2024), data produced as part of the evaluation study of the national action plan to combat desertification (Akdin et al., 2017), data collected during the field visits between 2016 and 2020 through semi-structured interviews and data from opensource documents and satellite images. Data analysis is assessed using basic qualitative variables (education level, income, age, family members, farming harvest, irrigation techniques) and systematic spatial comparisons of the IC variables and the environment's state of equilibrium observed in the oases.

Using data provided by the General Census of Population and Habitat (2014; 2024) of 44 rural communes we analyzed the common trends in IC richness and equilibrium. These communes are sampled among rural communes to represent the high mountain's oases, the intermediate piedmont valleys and the downstream areas, in the pre-desert domain.

In each rural commune five semi-directive surveys were led (a total of 220 surveys) to apprehend the socioeconomic variables inherent to the population's activities, the basic equipment (sanitation, drinking water, electrification, education, health and other services). We also apprehend the new public and private investments that characterize the local IC and may be useful to explore their significance in terms of environmental impacts. Particular attention was given to spatial similarities that may help in identifying homogeneous landscapes and provide pertinent indicators in linking the IC and its environmental impacts.

The impacts of modernization (modern intellectual capital) are apprehended considering their roles in the environmental equilibrium and resources (mainly water) consuming. The study focuses on the apprehension of the socioeconomic changes in the studied rural communes on local environmental balance, and how the Intellectual Capital of these oases influenced each situation over the last four decades. The communes are contrasted in this respect, and so are the associated practices and environmental equilibrium.

The mapping approach, based on the Geographic Information System (GIS) using ARGIS program is adopted to visualize the main contextual characteristics of the studied rural communes, mainly their geographic position, orography and hydrologic conditions along Ziz, Ghrib, Dades, Todgha, Mgoun and Draa rivers. The perceptions and characteristics of local IC (traditional versus modern practices, technic versus hand work tools; economic versus cultural parameters) were compared to the environmental indicators in different spatial units to apprehend potential links and causation processes.

A web survey based on Google form using 37 questions on environmental crisis perceptions, problems and suggested solutions.

4. Results

4.1. Spatial identification of environmental awareness: disparities facts and perceptions

The awareness of the environmental crisis is spatially changing in relation to intellectual capital and education in the studied area. The 44 rural communes studied tend to form clearly distinct socio-spatial groups based on their IC, education level and types of investments and entrepreneurship activities. The state of environmental equilibrium is clearly correlated with typical IC in each area. It allows a further understanding of the environmental repercussions in relation to human activities and suggest elements of implementation and sustainable strategies of local and regional development. The dominant perceptions among the population are negative (Table 2).

The major perceptions reveal that:

- Traditional cultural heritage decreases due to challenges of modern practices in investment and new modes of entrepreneurship development.
- The ongoing development model in oases tends to reinforce adverse effects of drought and water scarcity and makes the environment more vulnerable than before, due to the new exaggerated modes of water consuming in modern farms.
- Local socio-economic realities, themselves linked to population know-how, education level and intellectual capital, influence perceptions and vary enormously from one area to another.

Table 2. Perceived variability of Intellectual capital's (IC) influence on environmental equilibrium (interviewed persons ages between 40 and 55 years).

Spatial sectors	IC favors conservation	IC is muting but environmentally less risky	IC is weak, abusive resources use.	No idea, (now answer)	Total
High Mountain areas	80%	6%	4%	10%	100%
Valley and Mountain flanks	55%	25%	15%	5%	100%
Interface Mountain - plateaus	44%	26%	24%	6%	100%
Pre-desert with modern investments	14%	18%	65%	3%	100%

The technical modernism, as currently embraced and water-consuming projects encouraged by individual investments dominating in the south (modern farms on the pre-desert) are considered harmful to the environment and the sustainability of ongoing development by 65% of the interviewed population. Only 4% of this population think that abusive practices of water use occur in the upper mountain, where traditional modes of resources use are still active.

4.2. Modern vs traditional use of resources

The fieldwork and interviews undertook between 2016-2020 underline the fact that the main environmental characteristics of the studied communes, in relation to IC, have undergone profound changes over the past three decades. In several communes mainly downstream, these changes are negatively impacting the environmental equilibrium, historically achieved in several areas. This refers to the recent effects of economic modernization, the building extension in villages and cities, the international migration which improved population financial income, the new information and communication technologies and the intrusion of new practices and new resources' consuming modes into the local economy and society.

Such changes are noticeable through the demographic variables with a regional population of approximately 1.655.623 inhabitants centered along oases.

Traditional rurality is impressive in the economic, agricultural and livestock activities of most of the inhabitants in oases. They indicate the important developed Intellectual Capital as ancestral endogenous know-how that had ensured the sustainability of oases over the centuries. But in several parts, these territories are referred to as land of

migration, because they represent source areas of human flows to the north in the past and to Europe in the 20th century. These human flows were intense towards abroad in the sixties of the last century. The oasis socio-economic system has therefore been open and communicative, and the local Intellectual Capital consolidates inputs and benefit from external contributions and improvements.

The ambivalent characteristic of oasis migration in the last four decades is proven because it generates substantial cultural and financial contribution, mainly downstream where the modern economy is developing. The majority of interviewees (65%) in the most developed area downstream reported a negative environmental impact of emigration and modern activities, because they engender exaggerated modes of resources consuming, underground water pumping for domestic and agricultural uses as well as water pollution in urban centers. The degradation dynamics of the environment in these areas are therefore initiated when the interest in sustainable development is missing in local development. Another negative impact of emigration was highlighted in rural areas where young people that represent the potential active and working elites leave.

As a result, recent emigration is impacting Intellectual Capital in oasis and may be used among key factors to understand the evolution of environmental equilibrium and desertification.

Agricultural activities and livestock in the pre-Saharan zone are characterized by the following:

- a useful agricultural area estimated at 151,000 ha, where the "bour", meaning the non-irrigated crops, occupies approximately 51% (). The average size of farms is 2.38 ha.

- Animal breeding is dominated by sheep with a total number of 770,100, followed by goats (461,300) and cattle with a total number of only 46,600.

The system of transhumance in livestock farming, which dominated the history of oases is in decline and pushed towards the high peaks of the Atlas (Fig. 3).



Figure 3. Photograph illustrating the moving trend of livestock to the Summits of the Anti - Atlas Mountains in Saghro (between Iknioun and Nkob) at the province of Tinghir.

The provincial, municipal and local disparities are enormous in terms of land use, but some spatial homogeneous units are observed in terms of cultural heritage and environmental similarity (Fig. 4).

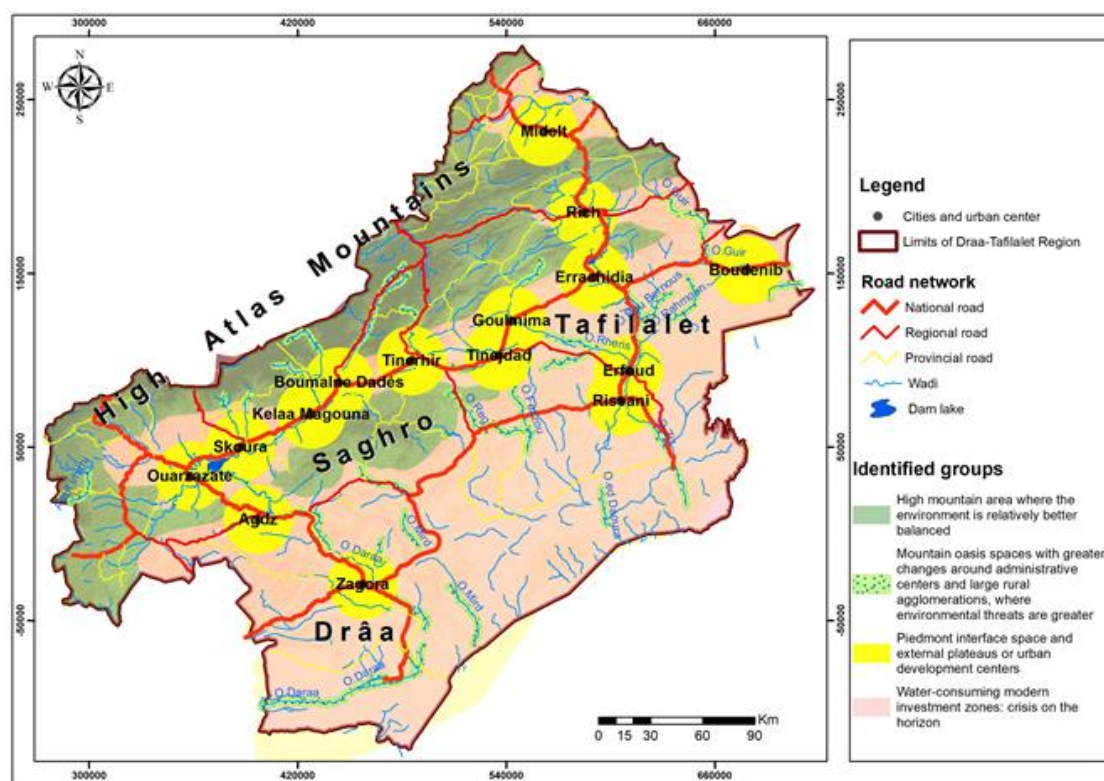


Figure 4. Spatial groups of interactive IC/environment in Draa Tafilalet Region

A large portion of the oasis agriculture is typical as it remains of subsistence. It is confined along valleys where surficial water is provided from rivers (Draâ, Ziz, Ghri, Guir, Dades, Todgha) and their tributaries.



Figure 5. Traditional agriculture challenging persistence: Todgha, Ait Youl, Province of Tinghir.

Traditional agriculture, as a facet of cultural heritage transmitted for centuries, is irrigated by the floods, frequent in rivers and tributaries using irrigation channels, manual

working tools and local solidarity practices, is still functional where heritage is preserved. In the uplands and higher valleys of the studied areas, water is supplied from springs or drained from rivers using a channels system (locally named *Targa* or *Saguia*) where the resource is optimized following norms collectively agreed throughout history. This traditional local system shows a rich cultural heritage and a high intellectual level in mastering environmental constraints.

Outside the valleys where surficial water disappears in dry seasons, agriculture is irrigated by new pumping underground water. It is a recent change that is widespread in lowlands downstream and outside the Atlas Mountain. The evolving modern agriculture, the underground water pumping and the building extension are causing severe negative impacts on the environment and contribute to active desertification. The lateral extension of the oases outside their traditional perimeter, the development of the new irrigated perimeters in the Dades, Ghriss, Ziz and Draa sectors, and the encouragement of agricultural investment consuming water, within the framework of the national agricultural program "Green Plan of Morocco", introduced critical techniques and new practices that marginalize environmental preoccupations in this area. Most interviewees (65%) agree with the fact that introducing modern actions that exaggeratedly consume water, are risky and may negatively influence the environmental balance that has been achieved because of the following reasons:

- new agricultural activities, building extension and modern investment often consume huge amounts of water and are sometimes polluting cities and rural habitats.

- The new sectors of modern exploitation (desert farms) with a different top management neglect conservative rules of the millennial Intellectual Capital accumulated by the oasis' communities.

- These new agricultural practices are considered "aberrant" and unfair in terms of water consumption, because they may in perspective, negatively affect the renewal capacity of resources and therefore influence local environmental balances. The environmental conservation perspectives are critical.

A major distinction is therefore observed in the studied oases between areas of traditional agriculture at the upper oases and areas of dense occupation in the south, where modern ways of life and economic activities, tend to marginalize subsistence agriculture and resources conservation while favoring alternative activities that negatively impact the environmental equilibrium. Significant confirming results are obtained from the factor analysis of data related to the studied rural communes.

4.3. *The modern economy and threatened equilibrium of ecosystems*

In Most studied communes the pressure on natural resources is observed. However, the environmental stress is higher in communes downstream mapped in Figure 3. The local IC in these communes is clearly changing due to the ongoing modernization. For several decades, the traditional agriculture is down as other new economic activities develop. This phenomenon might be explained by different variables such as demography (population growth), socio-economic, and technological changes. Locally, a new modern agriculture has grown outside the traditional oases as observed in watermelon farms at the vicinity of Zagora (watermelon production), in the sector of "young farmers" near Errachidia (Fig. 6), or in the new sector of "Mejhoul" dates between Errachidia and Boudenib. Underground water from the Cretaceous aquifers in these sectors is pumped to irrigate these new farms. Its level and reservoirs are progressively lower and weakened.

This type of agriculture develops while traditional rangelands in oasis decrease. Thus, following the cultural change and new economic practices, large modern farms have appeared on dozens of hectares in many pre-Saharan sites, outside traditional oases. These farms are irrigated mainly by groundwater pumping and exploited using modern farming techniques that, in some cases, do not consider ecosystem's vulnerability, such as water resources scarcity and sustainable ecological balances. The

open survey we carried out in April 2025 illustrates a major change in underground water use at oases.



Figure 6. Photograph illustrating the new irrigated farms integrated in future zones of crisis due to water deficits in the province of Zagora. (Source: Sabiri A. photo. 2023)

The Sources of this water, which represented 97% of total use three decades before, was lower to 22,7 %. Farming irrigation, which was rare at same time to 56% (Tab. 3).

Table 3. Underground water, used in oases. Source: Authors' field survey, 2025

Types of underground water use	Percentage (%)
Domestic use	22.7 %
Irrigation	56.0 %
Drinking water	18.7 %
Breed drinking	2.7 %
Total	100 %

4.4. Education, social change and environment

The social, spatial and economic changes mentioned above have impacted on the environmental balances of the oases. Emigration, new information and communication technologies and the new local economy in fact reflect the changes in the oases Intellectual Capital.

The deficit in the infrastructures persists everywhere in oasis rural areas. The reports of the Moroccan finance law (LF, 2020), underline the main investments granted to the Draa-Tafilalet rural region in the social fields (education, health, culture), and show that in recent years they have been concentrated in provincial capital centers and cities. The delay noted at this level is reported by human development indicators.

The illiterate population in rural areas remains dominant in most rural studied agglomerations. In 2014, it represented 27 to 52 in most villages and can reach 52% in some cases such as in Gourrama or Taghbalte villages (Table 4).

Table 4. Education level of the studied population (aged 15 years and more, in %).

Rural Commune	Population 15 years old and more	Pre-school	Primary school	Middle school	High school	University	Analphabet
Enzala (Rich, Ait El Abbas)	257	0.0	26.8	26.1	7.8	6.2	33.1
Gourrama (Rich, Ksar Kb)	1598	0.1	18.4	16.4	8.1	5.0	52.0
Zaouiate Sidi Hamza	711	1.2	38.3	18.6	3.2	1.8	36.8
Amerzegane (Tadoula)	528	3.6	34.0	12.3	10.0	2.6	37.6
Igherm N Ougdal	993	1.5	31.8	14.0	9.1	5.1	38.5
Afra (Idelsane, Skoura,)	1339	0.5	32.3	13.5	6.2	3.9	43.6
Alnif (Azkour Tinghir)	1472	1.0	28.3	26.0	9.2	4.8	30.7
Ait Sedrate Sahl el Gharb Ikouassene.	601	3.3	30.9	16.6	7.3	2.7	39.1
AitYoul (Jida Province Tinghir)	491	0.2	27.5	16.5	8.1	6.5	41.1
Imider (anounizm)	455	0.7	28.1	18.0	10.5	5.1	37.6
Taghzoute Nait Atta	1495	0.7	24.4	24.9	11.4	11.3	27.2
Afella N Dra (Ribat, Agdez)	1373	1.0	32.3	17.8	6.1	5.8	37.1
Nkob Ait Sllou, Agdez)	1924	0.2	20.3	18.7	10.9	7.0	43.0
Taghbalte (Ait Mnad)	2023	0.1	15.2	23.9	6.1	2.8	51.8
Tazarine (ImiNssite)	548	0.2	31.6	16.6	1.5	3.6	46.5
Tinzouline (BniZoli, Zagora)	2782	1.3	32.4	16.7	7.1	7.4	35.2

The population with a higher education level represents 5 to 10%. The literate population is mainly at the primary level, but the Middle school and the high school levels are gradually gaining importance among rural population in the area.

The territories' connectivity and communication tools offered to the population are factors of human development and inclusion in marginalized areas (Akdim, 2020; Hakikur 2006). In the south-eastern Morocco they are important, following the equipment efforts introduced by the government. The modern communication technologies are widespread. Telecom and Internet networks have territorial coverage

which exceeds 75%. However, the number of people who benefit from the service in rural areas often remains low. The rate of Internet use by the population is less than 22% throughout the whole villages under study (Table 5).

Despite the technological growth observed in this area, its impact to improve the average index of Intellectual Capital has not increased because it is influenced by the low level of education noted among peasants. The illiteracy is pervasive in rural areas. Most interviewees confirm that the Intellectual Capital over the oasis residents has recently declined, despite the technological growth of communication tools and the modern localized investments in farming outside the oases. It is worth mentioning that inherited environmental awareness becomes weak as major drivers of resources use are economic profit and increasing of individual income. As a result, critical environmental effects of modern projects and practices that increase water consumption or soil and vegetation degradation are increasing.

Table 5. Communication and Information Equipment in % in the rural communes (General census of population and habitat, 2014).

Rural Commune	Population	TV	Radio	Mobile Tel.	Fix Tel.	Internet	Computer	Satellite receiver
Enzala (Rich)	4390	48.9	26.4	87.0	0.1	0.7	1.6	45.4
Gourrama (Rich)	9314	55.9	23.8	76.1	1.3	1.8	5.9	53.6
Zaouiate Sidi Hamza	5454	77.0	35.2	82.1	0.0	0.3	1.6	76.5
Amerzegane	8697	94.3	48.5	93.2	3.0	6.6	10.8	92.0
Igherm N Ougdal	14801	95.5	56.3	95.2	1.2	5.2	8.5	93.2
Idelsane (Skoura)	8374	95.4	79.8	91.4	8.3	2.6	10.4	86.1
Alnif (Tinghir)	17996	93.3	15.5	96.2	8.7	2.4	10.4	87.9
Ait SedrateSahl el Gharbia	17376	92.8	26.9	95.9	4.5	6.2	11.6	88.2
Aït Youl (Tinghir)	4870	86.1	18.0	84.9	3.1	5.5	11.0	81.7
Imider	4420	84.8	14.4	93.3	3.8	8.0	21.7	82.9
Taghzoute Nait Atta	14669	92.5	76.6	95.9	10.0	8.2	16.4	90.8
Afella N Dra (Agdez)	7203	58.0	17.6	70.6	0.5	1.2	3.2	50.1
Nkob	7209	77.6	28.9	96.1	0.8	13.9	18.6	76.5
Taghbalte	10054	90.7	35.6	96.2	1.8	4.2	11.2	90.3
Tazarine	15069	87.3	36.1	95.9	4.4	9.4	14.4	86.1
Tinzouline (Bni Zoli, Zagora)	18941	94.0	70.6	96.5	0.7	5.2	9.5	86.6

5. Discussion

The observed change in oases' intellectual capital is reflected by the decline of traditional practices and wisdom that has previously allowed preservation of their

balance. At the same time, new practices that show little concern for these balances are increasing in the exploitation of resources with the dominance of profit logic.

The legal framework encouraging investment is poorly exploited in this case because it does not take into account investments adapted to the capacities of the environment and the sustainability of fragile environmental balances, in the context of climate change and ecosystems vulnerability.

The results of the survey confirm changing perceptions of the environmental threats among investors, young generations and most inhabitants that suffer in social segregation, ignorance and analphabetism. The formal and informal education may enhance awareness to environmental questions but seem inoperative where alphabets are still dominant.

The Intellectual Capital of oases' populations is deeply altered by modernity, technology and misuses of natural resources for example. The breeding methods in oases keep changing. The intensification and modern modes of resources' use is replacing the traditional farming. These ruptures are impacting the ecosystems and resources' stocks. Such investments are factors of land degradation and may have fatal consequences as observed in other Moroccan south regions such as in El Guerdane between Agadir and Taroudant where the overuse of underground water dries aquifers and snaps desertification. Their treatment must be among action priorities in the future.

5.1. Intellectual capital, opportunities, gains and local adaptive capacities

This study's outcomes show that intellectual capital is a key factor in environment preservation. The ongoing environmental crisis in oases is partly linked to neglecting environmental risks when adopting inopportune investing projects, mainly downstream. These areas have degraded dramatically due to the change of the IC, problems in populations education's levels and types of adopted modern investments. Modern mutations in economy, quality of life, building and other aspects reflected by the modern Intellectual Capital changes in the area are considered factors of the environmental degradation. The new oasis context is characterized by the following facts:

- technological growth is important as indicated by the development of new information and communication techniques and significant coverage by internet and telecom networks in the area. However, in several rural communes and for many social categories, their positive impact is not evident, because of financial or educational constraints or even by the lack of needed skills to optimize the use of the existing techniques. It is therefore obvious that in the major rural oases' communities are unable to take advantage of the internet development. The marginal communities disadvantage model (Hakikur, 2006) is confirmed. The model developed for innovation diffusion in the Ziz valley is still functional (Blaikie, 1979).

- The low level of education noted among peasants aged 15 years and over, and the pervasive illiteracy in rural areas are considered constraints that do not favor innovation in terms of natural resources conservatory alternatives. They are therefore factors of environmental degradation.

- The emerging new economic practices are abusively consuming resources in an arid environment and the development of modern investments and entrepreneurship that do not consider the increasing scarcity of water and natural resources increase the environmental vulnerability in oases. The crisis is reinforced by the context of aridity and

climate change. The excessive water consumption of modern farming projects (large desert farms) indicates a certain weakness in the environmental awareness of stakeholders (both public and private).

- The convergence of opinions expressed by the interviewed people underline that resources conservatory, as a component of the Intellectual Capital in oases, is weakened by the technological modernization and the education low level of the population's majority.

- The decline in traditionally balanced economic modes has been observed. It is faced with increasing modernization and new behavioral practices that are rarely respectful of the environment. This process affects ecological balances.

- The traditional extensive breeding and farming method which benefits from vegetation cover and grass on the mountain flanks, plateaus and plains is less adapted because the tribal traditions are changing, land property and landscape fragmentation do not facilitate the traditional large seasonal migration of sheep. The intensive agriculture land use along valleys is weakened by socioeconomic and cultural changes.

- New activities appear progressively on the oases, mainly downstream and outside the mountain areas. Building, administration and new services are progressively taking place mainly in the emerging centers and agglomerations. These mutations are negatively affecting the environment and frightening the underground water stock.

- The new modes of modern farming privileges, the quick economic income and disadvantage environmental equilibrium and the development sustainability. While creating the new facts, they engender nonreversible and unintentional destruction in interactive local ecological systems.

5.2. Sustainability for positive change in oases

The changes observed in the oases' rural development could have been made in accordance with the requirements of sustainable development based on the knowledge economy, the proper use of new information and communication techniques and the conservatory approaches of water and natural resources. Innovation in techniques and economic investments should strengthen the environmental balances in the area. The natural resources and landscape must be managed by precaution and awareness to avoid the commons' tragedy (Hardin, 1968, Bezin and Gregory, 2019.),

Urgent correction measures are necessary to reverse the observed harmful trends and engage new strategic actions to seize the niches of potential development in this area without frightening environmental equilibrium. The ultimate objective of these strategies may address conservatory approaches in link with development of fragile areas in oases and mountains. A better conceptual model of action integrating "Safeguarding and exploitation of resources for sustainable development" and a further apprehension of the conservatory logics and technics transmitted within the cultural heritage, may reinforce the Intellectual Capital accumulated through knowledge and the know-how in oases environments. These were basic elements that contributed to perpetuating harmony in landscapes and balanced resource renewal (natural, cultural, economic, etc.) for centuries. The extreme vulnerability of oases needs caution when

launching technical innovations or new economic and cultural practices, because their costs or generated additional costs can be huge and may threaten the local balances in economy, society and environment.

For many oases' residents, the crisis is deeper. "Anarchy" dominates as well as the modern exploitation of resources, the organization of space, the production or the marketing of products do not fit with sustainable development conditions. 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). This role is so essential today that regulatory gaps could be filled due to blocking or even the ineffectiveness of traditional control structures and the appearance of new organizational production and marketing structures and in several cases informal actors. The disappearance of traditional intellectual capital with solidarity structures and the increased domination of profit individual transactions and competition structures with new actors or modes of production and new modes of projects financing and bank credit are new problematic issues that should be addressed by the government and other concerned actors. As underlined elsewhere strategic proactivity and firm activity in environment is among priorities (Aragón-Correa, 1998; Aragón-Correa & Sharma, 2003). The managers competencies and education facilitate options of green entrepreneurship (Bansal & Roth, 2005). When landscape development indicates latent signals of crisis, the roles and responsibilities of actors should be redefined considering ways of strengthening the environmental balances and the sustainability of the developed actions implemented

The results of this study illustrate the pertinence considering IC among keys of environmentally balanced actions. These results support the idea of valuing the endogenous knowledge in environmental conservation (Davis, 2005). The units (downstream) where the IC knew a major change under new economic and social practices do not favor the environmental protection. The new techniques of resource management and financial investments were observed and herein illustrated and most interviewed population consider them as factors of environmental degradation. A more detailed analysis of the components of this new intellectual capital shows in fact, that increasing modernity of oases, occurs while ancestral practices, skills and local know – how are suffering. The heritage components of the Intellectual capital in oases tend to weaken. The conservation practices of water, vegetation and territory are receding or disappearing in the face of modernity and individual quest for maximum profit. The environmental effects of these new trends are degrading and are potential crises seeding for the future of the ecosystems.

5.3. Implementation: education, skills and the future

The younger population and adults are not sensitive to these environmental problems. Their generally low cultural and educational level does not encourage the creativity and wise action that is necessary for oasis sustainable development.

Alternative models of development should be reinvented, whereas the Intellectual Capital must be integrative to consider the spatially contrasted environmental contexts in the oases' domain. The critical sustainability of the development underlined in different

parts of the oases domain and the priority to reinforce resources' conservation in parallel with modern development initiatives in agriculture, building, services and other planned actions have to be framed the Intellectual Capital.

Education and sensitive actions are priorities to apprehend the environmental fragility in most rural communes, mainly downstream the valleys and in the piedmont. These facts should be considered in the cumulative Intellectual Capital process. The growing technological dimension (communication technologies, new farming investments, building activities), is not anymore sufficient to preserve the balanced environment. The environmental conservatory skills inherited from the past should be maintained and developed by training and public debate. The educational level of the population is important to consider favoring innovation and achieving sustainable development in the future. The IC approach is therefore important for corporative sustainable development and environmental conservation at present and for the future. It permits us to apprehend differences between spatial units with different degrees of development sustainability. It offers elements of debate and explanation useful to develop implementation ideas. As argued elsewhere (Vasyl et al., 2023), the mapping of these aspects are useful for diagnosis and solutions' implementation in several sectors, but its research perspectives are still widely opened, considering the ongoing progress, mainly in artificial intelligence or communication and information technologies.

5.4. Awareness strategies for segmented generations

It is worth noting that perceptions and behaviors towards the environmental crisis in oases are different. Several groups may be distinguished and as profiles be roughly characterized as follows: the dismissive, doubtful, disengaged, cautious, concerned and alarmed profiles. In terms of sensibilization and future action, each category must be treated differently. People of high education levels may understand and adopt modern solutions to save the environmental equilibrium using green technologies, communication and media for example. Younger generations may be sensitive to education (motivation, hackathons and arts (Biljana et al., 2022)). The financial motivations may be addressed to investors and modern farmers. Older generations are seemingly sensitive to direct communication using a P-to-P mode of convincing and discourses of ethics or even religious messages in mosques. All strategies may be pertinent to reinforce environmental awareness among people and serve the public interest.

6. Conclusions

The results of the study reveal the importance of intellectual capital for environmental understanding and management. In the fragile context of oases, the environmental state is correlated to human practices, themselves expressing changes underway in the Intellectual capital. Links between these two parameters were identified and perceived by most interviewees and expressed in units obtained by digital maps. The environmental equilibrium in oases is under stress, mainly in spatial units located down streams and at the piedmonts. The modern activities and building extension are intensively taking place in these areas.

The cumulative Intellectual Capital integrates a growing technological dimension (in terms of information and communication technologies and new farming investments), but the observed low level of residents' education, the prevailing illiteracy engenders a

strong loss of the environmental conservatory skills inherited from the past and the loss of reasoned adaptation practices. Negative trends in the oases' environment are therefore problematic. The importance of education, sensitive actions and training is underlined as a major component of local development and their geographic contrasts are mapped.

Recently, unfortunately actors tended to neglect the ecological fundamentals that have ensured the sustainability of the landscapes, full of cultures and traditional civilization. The densely occupied spaces using new business styles, entrepreneurship, ways of life, visions and aspirations of the new generations are identified. They are different from ancestral practices in units of the upper mountain. These changes seem to have negative impacts on the sustainability and environmental equilibrium of oases. A new model of entrepreneurship and local development linking the Intellectual Capital and environmental equilibrium, conditioned by the safe and conservatory use of natural resources is a challenge in the areas of crisis.

The rehabilitation of the ecosystems is not easy as many social and economic questions in the new realities must be resolved. The unintentional destruction in interactive local ecological systems is so complex to manage and may be irreversible in some cases.

No radical and immediate solutions exist, but strategies based on adapted Intellectual Capital for the future could be developed in an integrative global vision, using motivations, restrictive or coercive actions and more participation of concerned actors in conservation and sustainable development of the oases.

The approach adopted in the study shows that trends of modernization within the oases' Intellectual Capital must be framed by the sustainability foresight, where economic and technologic developments and human activities will be operated in harmony with issues of environmental equilibrium, heritage and civilizational futures. Developed intellectual capital allows bridging the nature culture gap to restore dynamic environmental equilibrium, maintain or produce its creative preservation.

Finally, in respect to the aims of this study, we did not further the alternative solutions that may bridge the ongoing process of modernity and landscape development in oases. Genuine solutions that may improve population income, jobs' creation and available resources in these fragile areas must be figured among research priorities in the future. Further prospective investigation is clearly needed.

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