Revista de Estudios Andaluces (REA) | Núm. 48, julio (2024) | e-ISSN: 2340-2776
https://dx.doi.org/10.12795/rea.2024.i48 | © Editorial Universidad de Sevilla 2024
https://editorial.us.es/es/revistas/revista-de-estudios-andaluces
https://revistascientificas.us.es/index.php/REA

Argania spinosa and *Tetraclinis articulata* seedling regeneration factors in the lower valley of Wadi Tamri (Morocco)

Factores que influyen en la regeneración de plántulas de *Argania spinosa* y *Tetraclinis articulata* en el valle inferior del Wadi Tamri (Marruecos)

Hicham Irifi
Hicham.irifi@usmba.ac.ma 0000-0003-4323-060X
Université Sidi Mohamed Ben Abdellah- Fès. Laboratoire Milieux naturels, Aménagement et Dynamiques Socio-spatiales (MNADSS). FLSH Sais-Fès.
Faculté des Lettres et des Sciences Humaines Saïs-Fés. BP 59 Route Immouzer. 30000 Fès, Maroc.

Abdellatif Tribak
abdellatif.tribak@usmba.ac.ma 0000-0002-1564-5886
School of Geography. Sidi Mohamed Ben Abdellah University.FLSH –SAIS.
BP: 59, Route Immouzer. 30000 Fès, Maroc.

INFO ARTÍCULO

Received: 07-11-2023
Revised: 16-03-2024
Accepted: 01-04-2024

KEYWORDS

Argan and thuya forest
Natural regeneration
Ecological and topographical variables
Landscape dynamics
Lower valley of Wadi Tamri
Morocco

ABSTRACT

The forest landscape of the lower valley of Wadi Tamri is a geographical space composed of interaction and perpetual dynamics elements. The degradation observed in the past results from often inadequate silvopastoral practices. Nevertheless, a light of hope for the future of this forest currently lies in the existence of the natural regeneration of the Argan and Thuya trees, the effect of the agricultural abandonment on the slopes following the rural exodus, the development of the forestry capital by the State and the impact of good management practices of natural resources adopted by the local population itself. To examine the dynamics of the forester landscape, we have prospected dozens of plots in the Argan and Thuya zones. In this sample, we counted the natural seedlings, conducted floristic surveys, and briefly described various ecological and geomorphological variables. Then, we developed a statistical database to spatialize and quantify this phenomenon with cartographic tools (GIS). The analysis of these dynamics highlighted the factors of installing young seedlings with all the necessary explanations. The results have clearly shown that the most significant families in this landscape include the *Asteraceae* and *Fabaceae* (13%), with the *Lamiaceae* (10%) following closely. Additionally, *the Euphorbiaceae, Solanaceae, Cistaceae*, and *Anacardiaceae* contribute the same percentage (5%). The remaining 18 families each constitute only 3%. Regeneration of young Argan and Thuya trees from seedlings displays varied morphologies, influenced by age and grazing effects, often accompanied by nursery plants. Rocks and blocks serve as significant shelters for seedling germination. Meanwhile, topographic analysis highlights the impact of differing slope gradients for this seedlings. Argan and Thuya seedlings both presents the highest percentage (40% and 50%) observed on mid-slopes and upper slopes. Notable presence of seedlings observed on various slope exposures, especially those facing West, North, North-West, and South-West. Field sampling reveals a correlation between natural regeneration and tree cover density, emphasizing the significance of medium-dense tree cover, even in humanized landscapes, with notable regeneration observed in abandoned terraces and formerly cultivated land in Thuya unit, showcasing ecosystem resilience in this region. Overall, this study offers a preliminary scientific foundation for further investigation into the natural regeneration of Argan and Thuya amidst ongoing climate change, while also serving as a cornerstone for decision-making in conserving these forest heritages.

DOI: https://dx.doi.org/10.12795/rea.2024.i48.07
Formato de cita / Citation: Irifi, H., & Tribak, A. (2024). *Argania spinosa* and *Tetraclinis articulata* seedling regeneration factors in the lower valley of Wadi Tamri (Morocco). *Revista de Estudios Andaluces*,(48), 133-150. https://dx.doi.org/10.12795/rea.2024.i48.07
Correspondencia autores: Hicham.irifi@usmba.ac.ma (Hicham Irifi)

PALABRAS CLAVE

Bosque de Argán y Thuya
Regeneración natural
Variables ecológicas y topográficas
Dinámica del paisaje
Valle inferior del Wadi Tamri
Marruecos

RESUMEN

El paisaje forestal del valle inferior del Wadi Tamri es un espacio geográfico compuesto por elementos de interacción y dinámica perpetua. La degradación observada en el pasado es el resultado de prácticas silvopastorales a menudo inadecuadas. Sin embargo, una luz de esperanza para el futuro de este bosque reside actualmente en la existencia de la regeneración natural de los árboles de Argán y Thuya, el efecto del abandono agrícola de las laderas tras el éxodo rural, el desarrollo del capital forestal por parte del Estado y el impacto de las buenas prácticas de gestión de los recursos naturales adoptadas por la propia población local. Para examinar la dinámica del paisaje forestal, hemos explorado decenas de parcelas en las zonas de Argán y Thuya. En ellas, hemos contado las plántulas naturales, realizado prospecciones florísticas y descrito brevemente diversas variables ecológicas y geomorfológicas. A continuación, elaboramos una base de datos estadísticos para espacializar y cuantificar este fenómeno con herramientas cartográficas (SIG). El análisis de esta dinámica destacó los factores que influyen en el establecimiento de las plántulas jóvenes, junto con todas las explicaciones necesarias. Los resultados han mostrado claramente que las familias más significativas en este paisaje son las *Asteraceae* y las *Fabaceae* (13%), seguidas de cerca por las *Lamiaceae* (10%). Además, las *Euphorbiaceae*, *Solanaceae*, *Cistaceae* y *Anacardiaceae* contribuyen con el mismo porcentaje (5%). Las 18 familias restantes constituyen cada una solo el 3%. La regeneración de árboles jóvenes de Argán y Thuya a partir de plántulas muestra morfologías variadas, influenciadas por la edad y los efectos del pastoreo, a menudo acompañadas de plantas de vivero. Las rocas y los bloques sirven como importantes refugios para la germinación de las plántulas. Mientras tanto, el análisis topográfico resalta el impacto de los diferentes gradientes de pendiente para estas plántulas. Tanto las plántulas de argán como las de thuya presentan el mayor porcentaje (40% y 50%) observado en las laderas medias y superiores. Se ha observado una notable presencia de plántulas en varias laderas, especialmente en aquellas orientadas al oeste, norte, noroeste y suroeste. El muestreo de campo revela una correlación entre la regeneración natural y la densidad de la cubierta arbórea, destacando la importancia de una cubierta arbórea de densidad media, incluso en paisajes humanizados, con una notable regeneración observada en terrazas abandonadas y tierras anteriormente cultivadas en la unidad de Thuya, mostrando la resiliencia del ecosistema en esta región. En general, este estudio ofrece una base científica preliminar para seguir investigando la regeneración natural del argán y la thuya en el contexto del cambio climático actual, al tiempo que sirve como piedra angular para la toma de decisiones en la conservación de estos patrimonios forestales.

1. INTRODUCTION

The Argan tree (*Argania spinosa* L. Skeels) and Thuya (*Tetraclinis articulata*) are the two most floristic species that occupy a significant place in the forest heritage. “Those two sylvo-pastoral species are characterized by an increased adaptation and endurance to face environmental stresses.” (El Finou *et al.* (2022). “They occupy about 1.751.300 hectares. They are the two largest forest species after holm oak (1 347 200 hectares).” (Lefhaili, 2020). “The Argan tree is of growing interest not only because of its crucial role in the fight against erosion and desertification but especially because of its crucial socio-economic role in traditional rural life.” (Faouzi & Martin, 2015).

The study of forest landscape dynamics has captured the attention of numerous researchers across various disciplines, including biogeographers, ecologists, economists, foresters, and planners. Each of these researchers brings unique perspectives and objectives to their study, leading to diverse approaches, purposes, and outcomes. They interested in understanding the distribution patterns of species within forest landscapes and how they are influenced by environmental factors such as climate and topography. Also, they may study forest dynamics to assess the economic value of forest resources, including timber production, carbon sequestration, recreational opportunities, forest management practices, biodiversity conservation, and ecosystem resilience. Those diverse scientific approaches lead us to a deeper understanding of the functioning and dynamics of forest landscapes. The study of the natural regeneration of some ligneous species and “relationships between agricultural practices and forest recovery in arid

 e-ISSN: 2340-2776 | doi: https://dx.doi.org/10.12795/rea.2024.i48.07

and semi-arid zones are poorly documented" (Genin *et al.* (2017). Some studies in the Cedar zone of Morocco highlighted the interest in the stationary conditions that influence the natural regeneration of *Cedrus atlantica* in the Moroccan Atas mountains (Ezzahiri & Belghazi, 2000). In the lower valley of Wadi Tamri, the argan forest presents a landscape of matorral quite degraded and essentially consisting of the association of stands of *Argania spinosa* and *Euphorbea beaumierana* distributed on the altitudes between 10m and 600m and *Tetraclinis articulate* associated with *Genista tricuspidata* and *Lavandula dentata* beyond 600m. These species are exploited under traditional use agro-sylvo-pastoral, including overgrazing, firewood, systematic harvesting of argan nuts, clearing and cultivation of undergrowth to create space for agricultural activities such as crop cultivation (cereal crops), pasture establishment, or orchard planting, etc. The degradation of this forest landscape and the difficulty of natural regeneration seem to result from human pressure on the space and the severity of the natural conditions. "The past and present regression of argan forests, in terms of density and total area, is mainly due to desertification, population pressure, pastoral activities, and the overexploitation of forest resources by the local population." (McGregor *et al*., 2009).

"Like many seed plants, the argan tree is naturally propagated by seeds. Its fructification usually begins at the age of 5 years, and the fruit yield depends on the genotype, age of the tree, management practices, and other factors, including climate and soil conditions" (Chakhchar *et al.* 2022). Thus, this natural regeneration presents a relevant example of the complexity that characterizes this forest landscape of the lower valley of Tamri. This regeneration has prospected in different localities, different orographic positions and exposure of the slopes, exploited or abandoned areas, and sometimes even near countryside. That makes this phenomenon complex, and the regeneration processes of young Argan and Thuya seedlings are still unknown. From the landscape point of view, it is a biotope of young argan and Thuya trees growing spontaneously if certain factors allow it. Factors such as soil composition, moisture levels, sunlight exposure, and absence of disturbances in some areas, may contribute to the favorable conditions necessary for the establishment and growth of these tree species. Observing the presence of young trees in the landscape provides valuable insights into the ecological resilience and potential for natural regeneration within the Argan and Thuya forest ecosystem. "The natural argan forest is expected to face major challenges. Drought is causing significant reductions in the natural distribution of argan trees, with the disappearance of the most exposed and vulnerable trees. This situation has been aggravated by the low rate of soil recovery due to the use of inappropriate farming methods and overgrazing" (McGregor *et al*., 2009; de Waroux & Lambin, 2012; Genin *et al*., 2017). "Forest decline in the argan woodlands results from a combination of lack of regrowth and loss of trees, which are in turn controlled by biophysical and social factors" (de Waroux & Lambin, 2012).

This work aims to study the characteristics of this natural regeneration as a landscape dynamic of the Argan forest of the lower valley of the Wadi Tamri, in a mountainous area and relatively preserved by establishing a site of biological and ecological interest of Tamri-Cap Ghir. The analysis of this forest landscape dynamic should highlight the regeneration factors and their explanatory parameters. We consider this natural regeneration of young seedlings of the Argan and thuya trees as a dynamic reverse of the forest landscape's degradation trends and a glimmer of hope for the future of this Argan zone. It is a natural regeneration that goes back more than 15 years and has reflected a series of natural and socio-spatial transformations and changes the region is experiencing. But it is clear that despite the effort made for its restoration, the overriding objective they have emphasized, namely regeneration and sustainability, has yet to be achieved. Still, the degradation continues at an alarming pace in terms of degradation and clearing (Laaribya, 2021). The main objectives of studying the factors influencing the regeneration of Argania spinosa and Tetraclinis articulata seedlings in the lower valley of Wadi Tamri, are: understanding Environmental Conditions, assessing human and climatic Impacts, and understanding the factors that facilitate the regeneration of Argan and Thuya seedlings for better making decision concerning the strategies aimed at promoting the natural regeneration and enhancing the resilience of forest ecosystems in the study area. Thus, we analyzed the implications of the results to establish a conceptual model of this natural regeneration of young argan and thuya seedlings.

2. STUDY AREA

The lower valley of Wadi Tamri is part of the Atlantic High Atlas 70 km north of Agadir. Its geographical situation, as well as geomorphological and bioclimatic, allows it to have a vegetal and forest landscape characterized by the presence of a significant floristic species of different origins (Mediterranean, Saharan, Macaronesian, and tropical) (figure. 1). It is a landscape that knows a perpetual dynamic given the close interference of the environment's human and physical components and the place it occupies in the rural economy. Indeed, it results from the interaction and combination of many biotic, abiotic, and anthropic factors (Irifi, 2023). Numerous potentialities characterize the forest landscape of the study area and know, on the contrary, several natural and anthropic constraints. One of the potentialities of this landscape is its floristic diversity, which is reflected by the presence of a significant number of species endemic to Morocco and to the region, including the Argan tree (*Argania spinosa* (L)-Skeels) that is the central element of this ecosystem as well as geosystem. "*Argania spinosa* (L.) Skeels is an endemic Moroccan tree subjected to a constant regression due to overexploitation. Germination and initial growth of seedlings are critical stages, and plant regeneration is strongly dependent on environmental conditions. Thus, the relationship between anthropogenic pressure, environmental conditions, and plant regeneration performance has become essential for understanding the germination dynamics of this native species, mainly because nowadays, its regeneration is essential for the conservation of the ecosystem that has merited the inclusion of the UNESCO Biosphere Reserve Arganeraie." (Zunzuneguia *et al.,* 2013). "The climate plays, on the contrary, the main role in the geographical distribution of the Argan tree" (Emberger, 1925). The green band of the Argan tree and *Tetraclinis articulata* forest in the area is marked by moderate thermal conditions if compared with neighboring regions such as the plain of Souss, the corridor of Argana, and the plateaus of Haha to the north (Irifi *et al*., 2020).

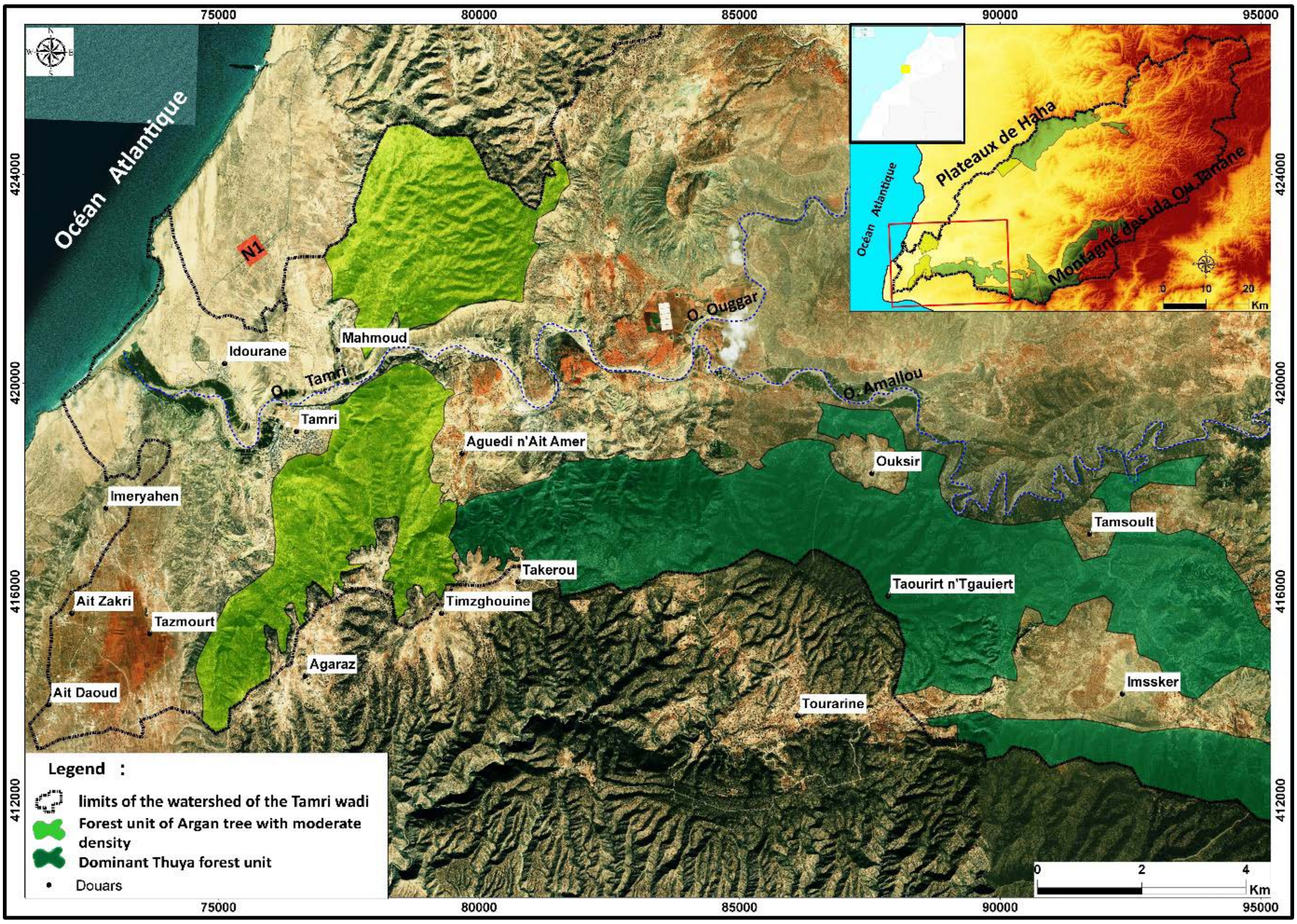

Figure 1. Geographical position of the lower valley of Wadi Tamri. Source: Irifi, 2023.

The climate, bioclimate and ecosystems in the Tamri region exhibit diversity due to the interplay of several factors (Irifi *et al.,* 2020):

- The proximity to the Atlantic Ocean, which moderates the local bioclimate;
- The presence of high topography to the south and southeast, offering protection from hot, drying easterly winds during summer, while low-lying topography to the north and northwest permits the passage of winter frontal rains;
- The cool mountainous area of Imouzzer des Ida Ou Tanane, which receives significant rainfall averaging 500 mm per year;
- The existence of a green belt consisting of Argan and Tetraclinis articulata forests, known for their milder thermal conditions compared to neighboring regions like the Souss plain, the Argana corridor, and the Haha plateaus to the north.

The distribution of rainfall typically changes from upstream to downstream and from southeast to northwest. It becomes apparent that precipitation diminishes from the hilltops to the valley floors and to the low-lying areas, resulting in significant aridity, especially in the lower Tamri valley (ranging between 242-284 mm) (El Ouahidi, 2008; Irifi, 2020; 2023).

In low valley of Wadi Tamri, tree forest constitutes the main element of its landscape. The Argan tree (*Argania spinosa* (Skeels L), the rustic tree that characterizes southwest Morocco, represents the majority of forest landscapes of the Western High and Anti Atlas and the Souss area. Its surface area tends to decrease every year because of the enormous pressure exerted on its ecosystems because of the considerable functions it performs. The argan tree is the most forester tree, being part of a geosystem that creates a dynamic in the region on a local and national scale. The man intervenes to build around him a cultural landscape linked to this agro-sylvo-pastoral geosystem. We note the presence of several plant communities in the lower valley of Wadi Tamri, divided between two forest areas, which are the forest of Ida Ou Throuma to the north and northeast of the watershed, and the forest of Ain Tamaloukt, which occupies part of the sub-watershed of Ida Ou Tanane to the south of the watershed of Wadi Tamri (El Ouahidi, 2008). Here, the Argan tree, which corresponds bio-climatically to the infra-Mediterranean stage, dominates the altitudes between 240 and 540 m and is associated with *Periploca leavigata*, *Pistacia lentiscus*, *Lavandula dentata*, and *Tetraclinis articulata* at altitudes over 550 m. The Arganeraie occupies various geological substrates; it is also a sandstone cover softer than white limestone and yellow clays than green marl of the Cretaceous stage. (Abouri, 2008). Forester landscape unit with Thuya presents a dominance of Thuya tree (*Tetraclinis articulata*) in association with *Genista tricuspidata*, *Lavandula dentata*, *Ceratonia siliqua*, *Thymus satureoides*, *Pistacia lentiscus*, *Phillyrea latifolia*, *Quercus rotundifolia*, *Olea maroccana*, *Globularia alypum*, *Rhamnus lycioides subsp*, *Periploca laevigata*, *Asparagus albus*, *Gymnosporia senegalensis*, *Rhus pentaphylla*, *Cistus villosus*, *Ephedra fragilis subsp*, *Smilax aspera*, *Chamaerops humilis* (Irifi, 2020). These forest unit corresponding to the Thermo-Mediterranean stage develops from 500 to about 800 m of elevation (figure 2).

The delimitation of these two homogeneous forester landscape units was based mainly on highlighting a lot of geographical, orographic, bioclimatic, biogeographic, and anthropic criteria, which determine the phenomenon of natural regeneration of the Argan and Thuya trees. Although the density of the tree cover in these two landscape units is essential, the floristic diversity in the undergrowth of the argan and the Thuya trees makes it possible to preserve the good functioning of these forest landscapes, which ensures in part of the natural regeneration of the two trees. The recurrence and the long periods of drought and the nature of the resource utilization system represent significant difficulties that constrain natural regeneration processes. The agrarian system of the argan forest of the Haha- as well as the Ida Ou Tanane-is based on three major productions: the argan tree and its production of argan nuts (*argane*), the breeding of small ruminants, mainly goats (*taghate*), and the cultivation of cereals, principally barley (*tomzine*) (Faouzi, 2011). The argan tree has the characteristic of being perfectly integrated into local production, where it forms the essential component of the entire management system of the natural environment.

 | e-ISSN: 2340-2776 | doi: https://dx.doi.org/10.12795/rea.2024.i48.07

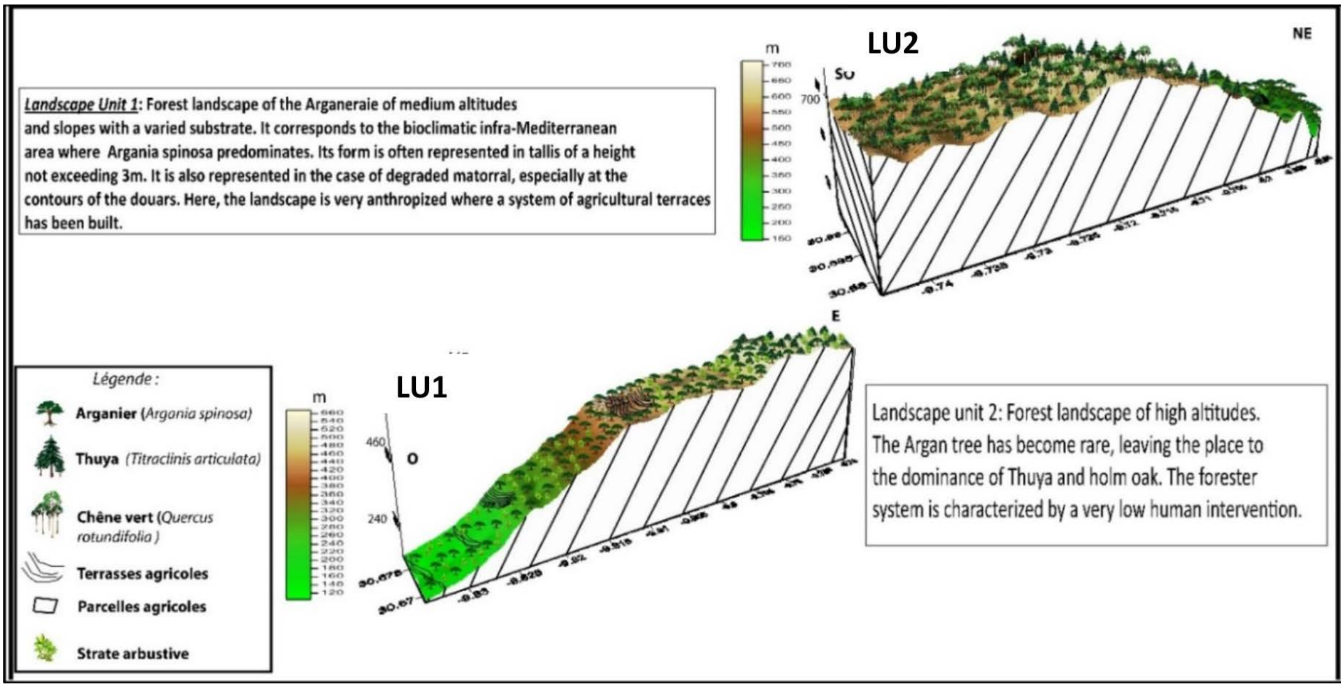

Figure 2. Forester landscape units of the lower valley of Wadi Tamri. Source: Irifi *et al*., *2017*.

3. METHODOLOGY

3.1. Data and working methodology

In this study, we applied a systemic and multidisciplinary approach to study the factors acting on the dynamics of the forest landscape. On a total area of 3704.41 hectares for the moderately dense Arganier unit and 23005.16 hectares for the dominant Thuya forest unit, we adopted an applied methodology to realize floristic surveys. For this reason, we begin the work by a sampling mesh of forest landscape units studied in the framework of our Ph. D thesis, evaluating 160 circular plots spaced between 300 meters and distributed unevenly between the forest unit of Argan tree with moderate density (88 plots), and the forest landscape of dominant Thuya unit (72 plots) (figure. 3). The spatial boundaries of these forest units are delineated on the landscape unit map of the Oued Tamri watershed, relying on two primary criteria. Firstly, the density of forest cover is assessed, categorized as medium density for the Argan tree and high density for the Thuya unit. Secondly, a botanical and ecological criterion is employed, emphasizing the occurrence of two dominant woody species characteristic of the mountainous regions of the Atlantic High Atlas: Argan and Thuya, alongside a relatively diverse floristic composition (Irifi, 2023).

The fieldwork for this study took place from May 2018 to July 2021 in the two forest landscape units, also, the vegetation inventory was often carried out at the end of the rainy season. Systematic sampling stands out as one of the most suitable methods for tackling the problematic of natural regeneration among young Argan and Thuya seedlings. This method entails employing a systematic grid of points, acting as survey or measurement stations, evenly spaced at regular intervals. The method retains a probabilistic nature if at least one coordinate of the initial point is chosen randomly. Under these conditions, all points within the surveyed area theoretically possess an equal probability of selection. Implementation may involve randomly selecting survey points from a detailed topographical map. During fieldwork, it becomes essential to exclude specific points corresponding to irrelevant features, such as roadsides or buildings (Le Floc'h *et al.*, 2008; Glèlè Kakaï et al., 2016). Thus, in the fieldwork, the sampling is systematic and random. This method establishes floristic and phytosociological surveys and a summary description of different ecological and geomorphological variables.

The vegetation study in the evaluated plots proceeded through the following stages:

- Utilization of satellite imagery obtained from the SAS.planete image sensor.
- Implementation of a sampling plan encompassing plots selected to ensure a reasonably high level of representativeness for each forest landscape unit.
- Identification of plant species within each assessed plot, with differentiation of families and categories of endemics. This involved referencing materials such as the book "Espèces remarquables de la flore du Maroc" by Aafi *et al.* (2002), the PhD thesis by Peltier (1982), the book by Benabid (2000), and Irifi (2021), as well as the utilization of the "PlantNet" Smartphone application and geographic information systems.

The inventory includes variables of the field conditions (elevation, slopes, bedrock, soil, exposure of slopes), as well as then ecological variables related to the Argan and Thuya trees in the plot (density of tree cover, fruiting, regeneration, health status, topping, the rate of recovery of the shrub layer) of this mountainous area. Finally, a part of the floristic survey canvas is reserved for the natural regeneration of the Argan tree and Thuya, counting the number of seedlings and their characteristics. The main objective behind this type of sampling is to establish a statistical database to quantify the phenomenon and spatialize it by cartographic tools (GIS). Field data is utilized to explore the correlation between natural regeneration and site-specific conditions, including lithology, soil type, elevation, slope, aspect, and anthropogenic influences. Furthermore, those samples are exploited to create a conceptual model of this phenomenon. This mapping makes it easy to compare plots that are experiencing natural regeneration with those that are not. The natural regeneration of forests is influenced by emergent processes occurring at both local and landscape levels (Arroyo-Rodríguez *et al*., 2016). The potential for natural regeneration increases with proximity to existing forest remnants, higher rainfall, and greater soil fertility (Uriarte & Chazdon, 2016).

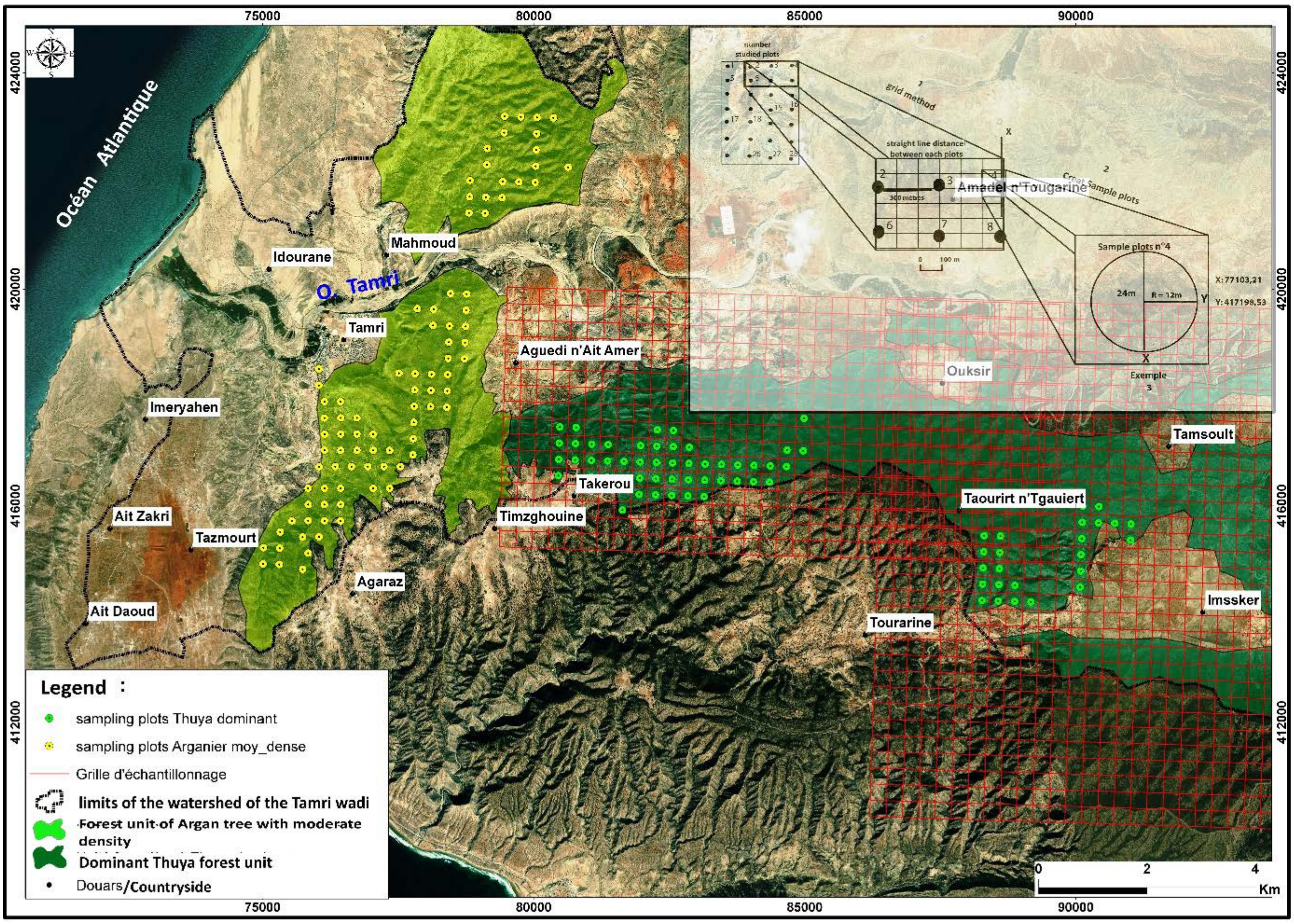

Figure 3. Map of grid sample and systematic plot sampling plots using ArcGIS. Source: Irifi, 2023.

To analyze the phenomenon of natural regeneration of Argan and Thuya trees, we first entered the data collected from the field to organize and classify them for statistical analysis in Excel. Then, we linked the plots with the corresponding unit, integrating them in a Geographic Information System (ArcMap) to spatialize them. During fieldwork, we utilized MAPinr smartphone application, which incorporates KML/KMZ extensions of our sampling plot grids, to aid in their identification and streamline the process. Certainly, the integration of GIS and statistical analysis provides a powerful toolset for examining the status of forest landscape regeneration. After preprocessing the data using the Excel and ArcGIS programs (https://www.esri.com), including geometric corrections, data connection, and the spatial interpolation method combined with physical analysis of the digital elevation model and visual interpretation were adopted using the SAS. planete images, to validate certain physical conditions and to gain a global vision of the study area. We downloaded The digital elevation model (DEM) from the Vertex platform (https://search.asf.alaska.edu/) with a 12.5 m resolution per pixel provided by the ALOS-POLSAR sensor. The spatial interpolation or data geostatistical analysis is a local neighborhood approach "based on the assumption that each point influences the resulting surface only up to a certain finite distance. Values at different unsampled points are computed by functions with different parameters, and the condition of continuity between these functions is defined only for some approaches" (Mitas & Mitasova, 2005). "Spatial interpolation, therefore, aims at estimating values of a spatial phenomenon or function (temperature, elevation, etc.) at unobserved/estimated points, given values of the phenomenon at observed/estimated points" (Ikechukwu *et al*., 2017). "Interpolation becomes very useful and essential in scenarios where, the resolution, orientation, or cell size of a discretized surface varies from what is needed. It is also employed when a continuous surface is represented by a data model different from what is desired, and when data spread does not cover an area of interest totally" (Burrough & McDonnell, 1998; Ikechukwu *et al.,* 2017). The spatial interpolation approach includes many spatial generalization methods such as Inverse Distance Weighted IDW, Kriging, Spline, Topo to Raster... "The method of point selection used for the computation of the interpolating function differs among the various methods and their concrete implementations" (Mitas & Mitasova, 2005).

In our processing analysis, we adopted the IDW method (Inverse Distance Weighted) for predicting and generalizing our results. "This is one of the simplest and most readily available methods. It is based on an assumption that the value at an unsampled point can be approximated as a weighted average of values at points within a certain cut-off distance or from a given number of the closest points (*typically 10 to 30*)" (Mitas & Mitasova, 2005). Based on the Course on Quantitative Vegetation Measurement Methods (Mohammed, 1994), the classes adopted to assess the state of natural regeneration of the Argan and Thuya trees are highlighted in table 1. In the sample plots that recorded from 1 to 2 seedlings, we joined them to the low regeneration class. Then, we assigned each sample plot to a moderate to dynamic state of regeneration that recorded some 3 to 5 seedlings. Each sample plot that exceeds this number of Argan and Thuya seedlings is assigned to the active regeneration class (table 1). The study also considered the relationship between species and natural regeneration in response to changing climatic conditions. This aspect was examined to illustrate the extent to which the significance and feasibility of natural regeneration are influenced by this abiotic factor of the landscape.

Table 1. Classes of natural regeneration of Argan and Thuya trees in the study area.

State of regeneration	Number of seedlings /ha
None	<20
Low	20 à 40
Moderate	40 à 80
Dynamic	80 à 90
Very dynamic	>90

Source: own elaboration based on Mohammed, 1994.

 | e-ISSN: 2340-2776 | doi: https://dx.doi.org/10.12795/rea.2024.i48.07

4. RESULTS

The state of the forest landscapes of the two units and consequently of the natural regeneration translate the strong covetousness: overgrazing, overexploitation of the ligneous resources, an intensive culture, systematic collection of the fruits, to which are added the intricate ecological conditions and the fires. That explains the low natural regeneration rate of the Argan and Thuya trees in the study area. Generally, a detailed study of the phenomenon of natural regeneration is necessary to reveal the factors that condition its installation. Three essential constraints destroy this positive phenomenon of the forester landscape: The systematic collection of fruits by the local population; The consumption of the fruits of the argan tree by the herds during the grazing and the intricate ecological conditions.

The Fieldwork conducted in the lower valley of Wadi Tamri shows the presence of natural regeneration of argan and Thuya trees by seedlings in some areas open to the range. The young seedlings could be regenerated in high altitudes, as in topographic depressions, on steep slopes, flat grounds, or abandoned agricultural terraces. It is also important to note that natural regeneration could be more robust and present in some conserved areas with dense tree cover and less anthropized. Hence, natural regeneration processes remain intertwined with site-specific conditions, encompassing both biotope and geosystem characteristics.

The young argan and Thuya trees regenerated by seedlings present a more or less similar morphology with variable heights and diameters from 30 cm to 1.50 m according to the age of the regeneration, of which certain young seedlings have a shape in tuft that indicates the effect of the grazing. Indeed, many young seedlings of the Argan and Thuya trees have been successfully initiated with nursery plants such as *Lavandula dentata*, *Genista tricuspidata*, *Genista ifniensis*, *Salsola vermiculata*, *Pistacia lentiscus*, *Periploca laevigata* ..., of which about 39% for young seedlings of Argan tree and almost 41% for regenerated seedlings in the forest unit with dominant Thuya. For both landscape units, the blocks or rocks present a considerable shelter for the germination of young seedlings; 33% of seedlings in the forest unit with medium dense Argan tree and 17% for the dominant Thuya class, have seen that 43% of natural regeneration, is observed on the ridge of Anklout anticline. The study of topographic factors reveals their impact on the natural regeneration of Argan and Thuya, of which more than 36 young seedlings of Argan were regenerated on low to medium slopes ranging from less than 15% to 45% (table 2), and almost 118 young seedlings of Thuya (table 3). The highest percentages of argan seedlings are recorded in the mid-slopes (40%), followed by 24% for the plots assessed in the upper slopes and 20% for the sample plots in the lower slopes, while the ridges represent only 13% of natural regeneration. In the thuya unit, seedlings are also more regenerated on mid-slopes (50%) and ridges (43%), while they become rare when approaching the lower slopes due to the extremely steep slopes (tables 4 and 5).

The geomorphological and orographic effect is apparent in the role of slope exposure and altitudes. For the unit of the Argan tree, more than 38 seedlings are observed on slopes facing West, North, North-West, and South-West, and 78 young seedlings are within the forest unit of the dominant Thuya tree (table 6 and 7). For the argan tree that developed in altitude ranging from 10 to 600m in the study area, we recorded a high regeneration between 200 to 300m and altitudes over 300m (table 8). In contrast, the role of elevation in the dominant Thuya Forest unit positively impacts regeneration at elevations between 500 and 700 m (122 young seedlings) (table 9).

Table 2. Number of seedlings per slope class in the Argan with moderate density tree unit.

Number of seedlings per slope class (%)				
< 15 %	15 à 30 %	30 à 45%	45 à70 %	> 70 %
11	16	9	10	9

Source: our floristic surveys.

© Editorial Universidad de Sevilla 2024 | Sevilla, España| CC BY-NC-SA 4.0. | e-ISSN: 2340-2776 | doi: https://dx.doi.org/10.12795/rea.2024.i48.07

Table 3. Number of seedlings by slope class in the dominant Thuya unit.

Number of seedlings by slope class (%)				
< 15 %	15 à 30 %	30 à 45%	45 à70 %	> 70 %
102	14	2	3	6

Source: our floristic surveys.

Table 4. Number of seedlings by topographic position in the Argan tree with moderate density unit.

Cliff	Upper-slope	Mid-slope	Lower slope	Talweg	Flat	Depression	Ridge
0	13	22	11	2	0	0	7
0%	24%	40%	20%	4%	0%	0%	13%

Source: our floristic surveys.

Table 5. Number of seedlings by topographic position in the dominant Thuya unit.

Cliff	Upper-slope	Mid-slope	Lower slope	Talweg	Flat	Depression	Ridge
0	22	131	33	5	19	0	74
0%	8%	46%	12%	2%	7%	0%	26%

Source: our floristic surveys.

Table 6. Number of seedlings by exposure directions in the Argan tree with moderate density unit.

Number of seedlings per exposure direction							
North	N-W	West	S-W	South	SE	East	None
12	4	17	5	10	1	3	2

Source: our floristic surveys.

Table 7. Number of seedlings by exposure directions in the dominant Thuya unit.

Number of seedlings per exposure direction							
North	N-W	West	NE	South	SE	East	None
110	39	42	28	9	10	42	4

Source: our floristic surveys.

Table 8. A number of seedlings per altitude class in the Argan tree with moderate density uni.

Number of seedlings per altitude class (m)				
<100	100 à 150	150 à 200	200 à 300	>300
2	8	8	23	14

Source: our floristic surveys.

Table 9. Number of seedlings per elevation class in the dominant Thuya unit.

Number of seedlings per elevation class (m)				
<400	400 à 500	500 à 600	600 à 700	>700
0	2	57	65	3

Source: our floristic surveys.

The sampling that we conducted in the field showed us a correlation between natural regeneration and the density of tree cover, including more than 50 young seedlings of argan were recorded between coverage of 5 to 45% for the argan unit and 110 young seedlings in the dominant Thuya unit (figures 4 and 5). These results reveal the importance of a medium-dense tree cover with important fruiting even within the humanized or overgrazed landscape. Moreover, in the landscape of the dominant Thuya unit, we note that the plots in which the natural regeneration of young seedlings is significant are somewhat abandoned terraces or land formerly cleared and cultivated near douars Takerou and Bou Ferdou as we will demonstrate in the map below (figure 6). We also note that within this unit dominated by *Tetraclinis articulata*, we recorded the natural regeneration of young seedlings of argan tree of variable heights, sometimes exceeding 1 m, which proves their more or less seniority.

The correlation coefficient between the number of seedlings and the slope values presents a positive value close to zero for the moderately dense Argan tree forest unit (r=0.028), which means a weak linear relationship and that the two variables (slope and number of seedlings) do not necessarily move in the same direction. Generally, the average slopes favor the natural regeneration of young seedlings of the Argan tree. On the contrary, the results of the forest unit with dominant Thuya show a negative correlation (r = -0.0195), which means that the two variables move in opposite directions. The same applies to the altitude factor and number of seedlings for the two forest landscape units. They show a negative value of the correlation coefficient or close to zero, indicating that these two variables do not necessarily influence the natural regeneration of young seedlings of Argan and Thuya, or the two physical factors may have a combined influence or depend on a third or several factors.

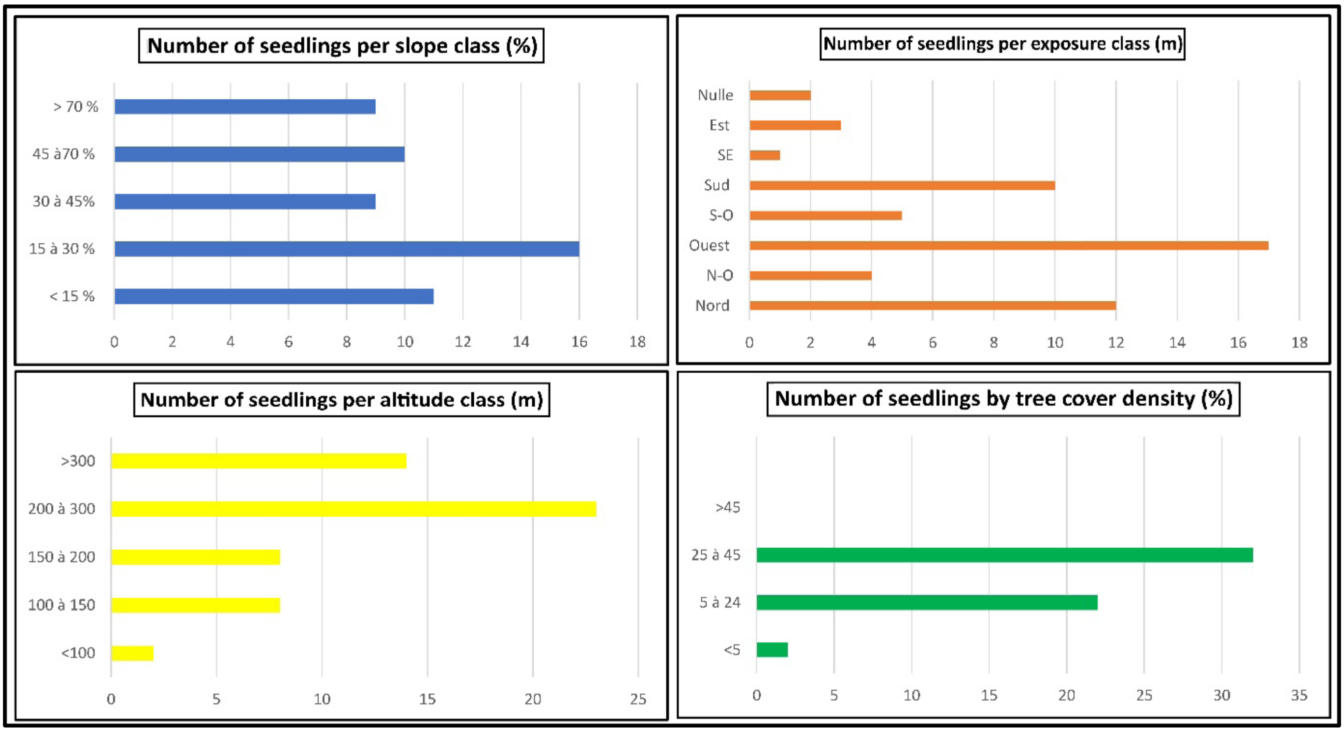

Figure 4. Diagrams of the number of seedlings by field conditions in the Argan with Moderate density unit. Source: our floristic surveys.

 | e-ISSN: 2340-2776 | doi: https://dx.doi.org/10.12795/rea.2024.i48.07

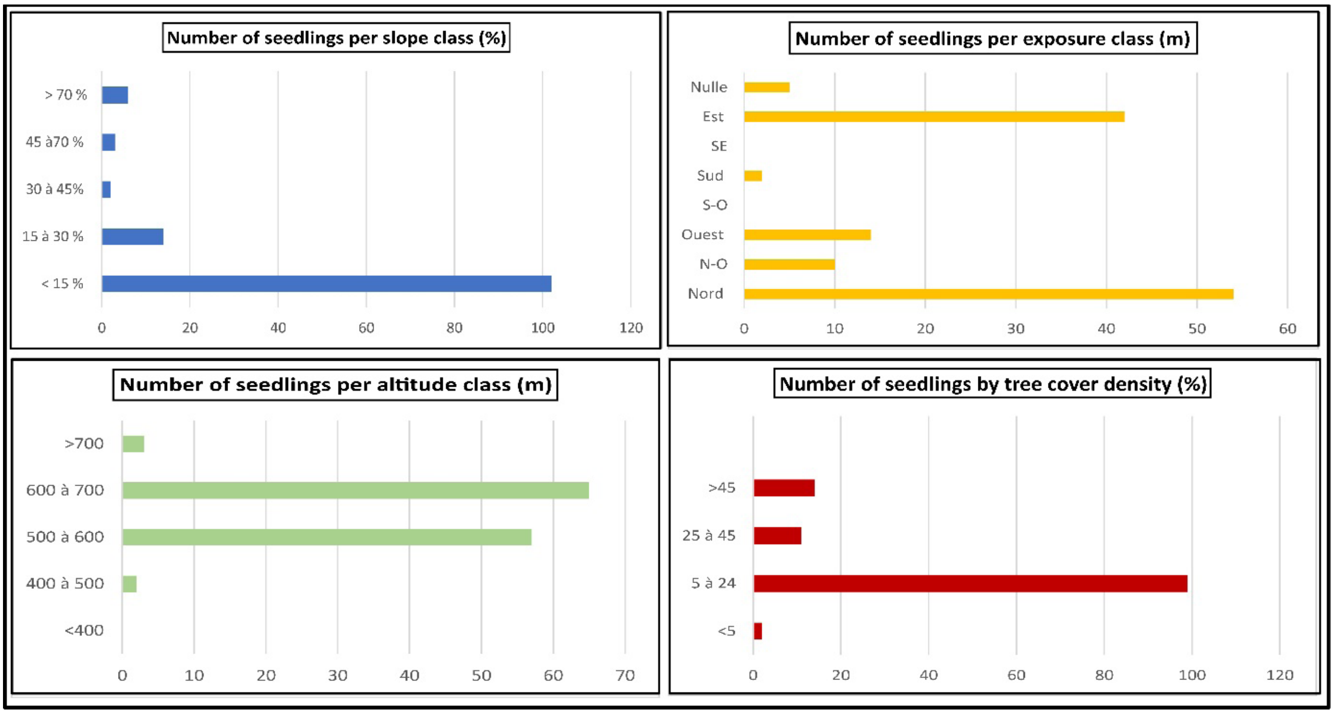

Figure 5. Diagrams of the number of seedlings by field conditions in the Thuya dominant unit.
Source: our floristic surveys.

The Spatialization of these regeneration data based on the IDW interpolation method under ArcGIS software generalizes the results to geolocate the areas with natural regeneration of young seedlings per hectare: null, weak, moderate, and dynamic as thinned in Table 1 above. In detail, the two maps (figures 6 and 7) show a natural regeneration of the two species generally, weak and highly concentrated in the form of a core. The dark green color corresponds to a dynamic natural regeneration in plots where we recorded more than four seedlings of the argan tree and more than 36 young seedlings of Thuya in the upper landscape unit. This class has a minimal area (0.20%) for the unit of the argan tree. All that is in light green corresponds to the class of the state weak to moderate regeneration between 20 to 40 seedlings per hectare. This class represents 9% of the argan tree unit and 59% of the total area of the dominant Thuya unit. 3.38% was estimated as the class of moderate and dynamic regeneration, which is almost 88.75 ha of the forest unit of the Argan tree. However, it represents 13% of the total area of the dominant Thuya unit, which is more than 909.65 ha. It corresponds to the sample plots in which we found 3 to 5 young seedlings, which are probably located in the shelter of the grazed areas and often in the West and North and NW exposure, or in abandoned agricultural terraces which have known since these last decades a vegetal reconquest. The shrub cover is grown and has a high degree of recovery. The main species recorded are Genista ifniensis, *Genista tricuspidata, Lavandula dentata, Sedum sediform, Cistus salviifolius, Cistus villosus, Ononis natrix, Olea europaea, Chamaeycitisus albidus, Periploca leavigata, Pistacia lentiscus, Rhamnus lycioides, Senecio antheuphorbium*.

Indeed, the topographic parameters influence less the natural regeneration of the argan tree. The low slopes can affect the processes of trapping argan nuts. However, they can be a cause of disruption of the ecosystem since the land becomes more accessible to herds. The exposure of the slopes has undoubtedly a positive and considerable effect on the natural regeneration on a large scale, especially for the slopes exposed to the North, NW, W, and SW. They guarantee a continuous supply of relative humidity during the day and night, limit evapotranspiration, and allow the young seedlings to exceed the summer period slightly. Regardless of the bedrock type and the soil depth, young seedlings natural regeneration depends on the site conditions. Instead, the microtopography, the geomorphology, the moisture, and the situation with the sea can constitute the main parameters that influence the installation of this regeneration, but also the structure and the thickness of the edaphic mantle silty clay. Figure 8 presents a conceptual model of the natural regeneration of young seedlings of the argan tree, which we have developed based on our understanding of the processes of evolutionary dynamics of the general forest landscape on the one hand, and the parameters interacting with the phenomenon on the other hand. Generally, natural regeneration is possible if the conditions and the installation factors are favorable to the trapping, dissemination, and germination of the drowning argan and thuya trees (figure 8).

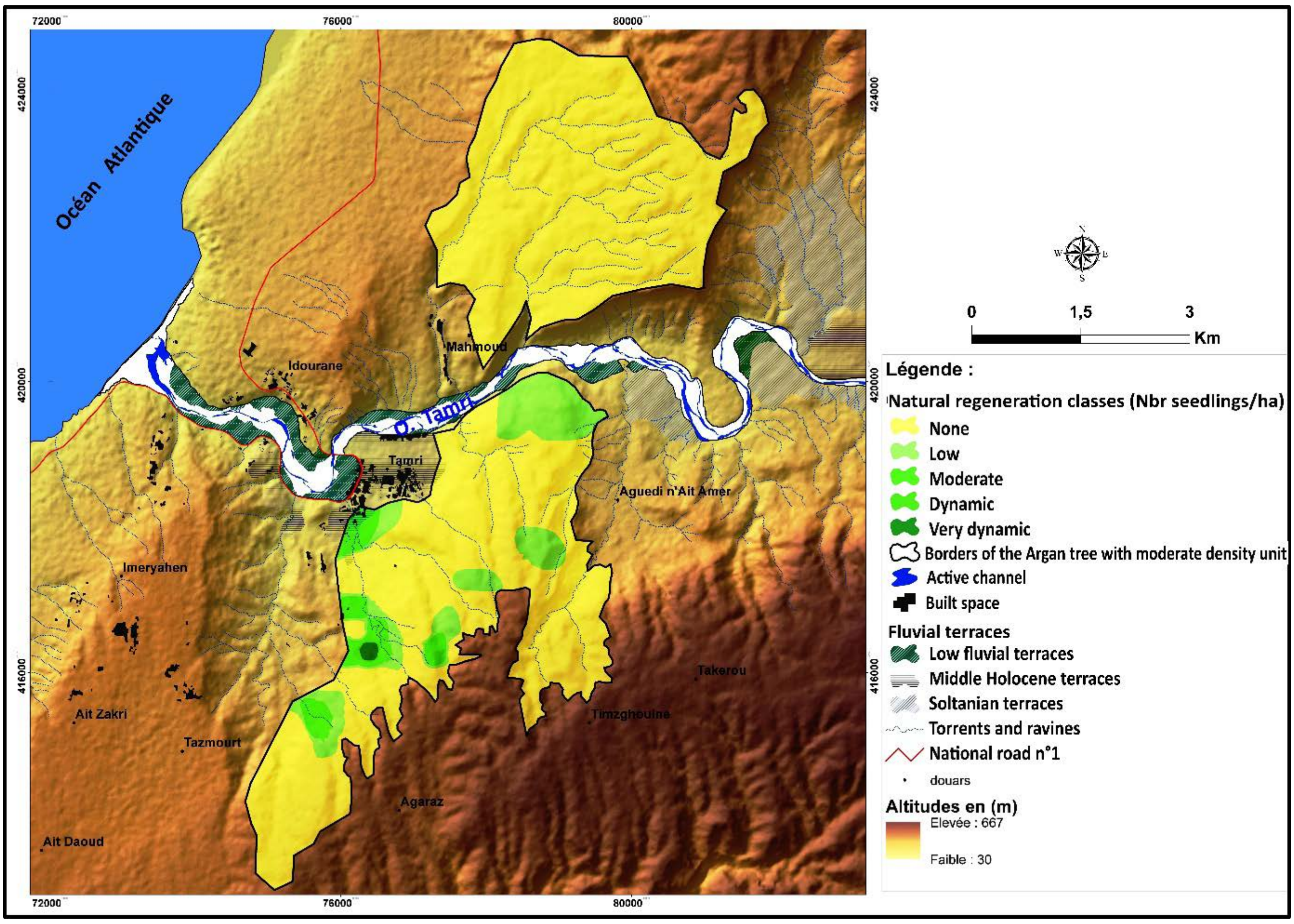

Figure 6. Map of natural regeneration of young seedlings of the argan tree in the argan with moderate density. Source: our floristic surveys and IDW.

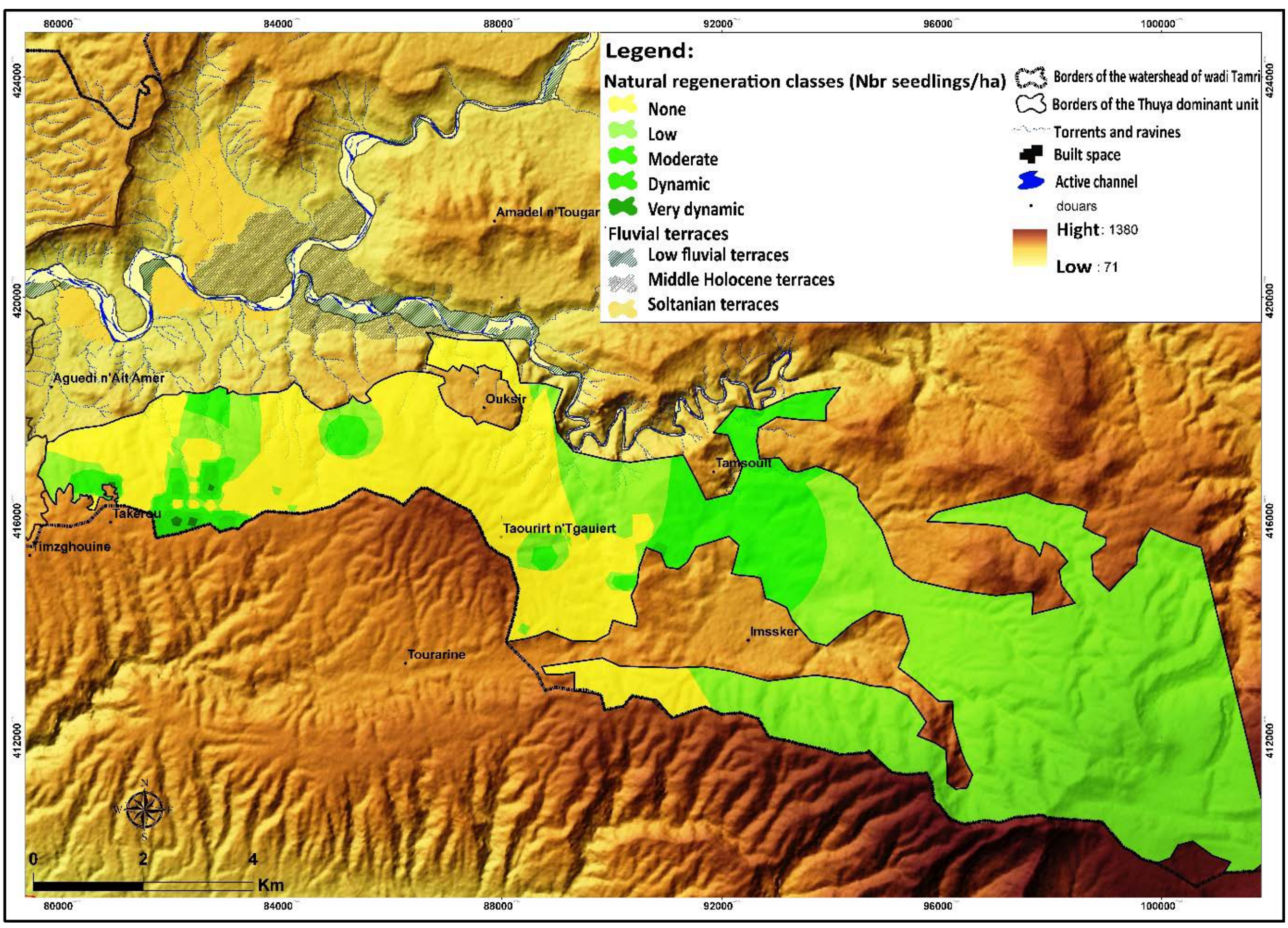

Figure 7. Map of natural regeneration of young seedlings in the Thuya dominant unit. Source: our floristic surveys and IDW.

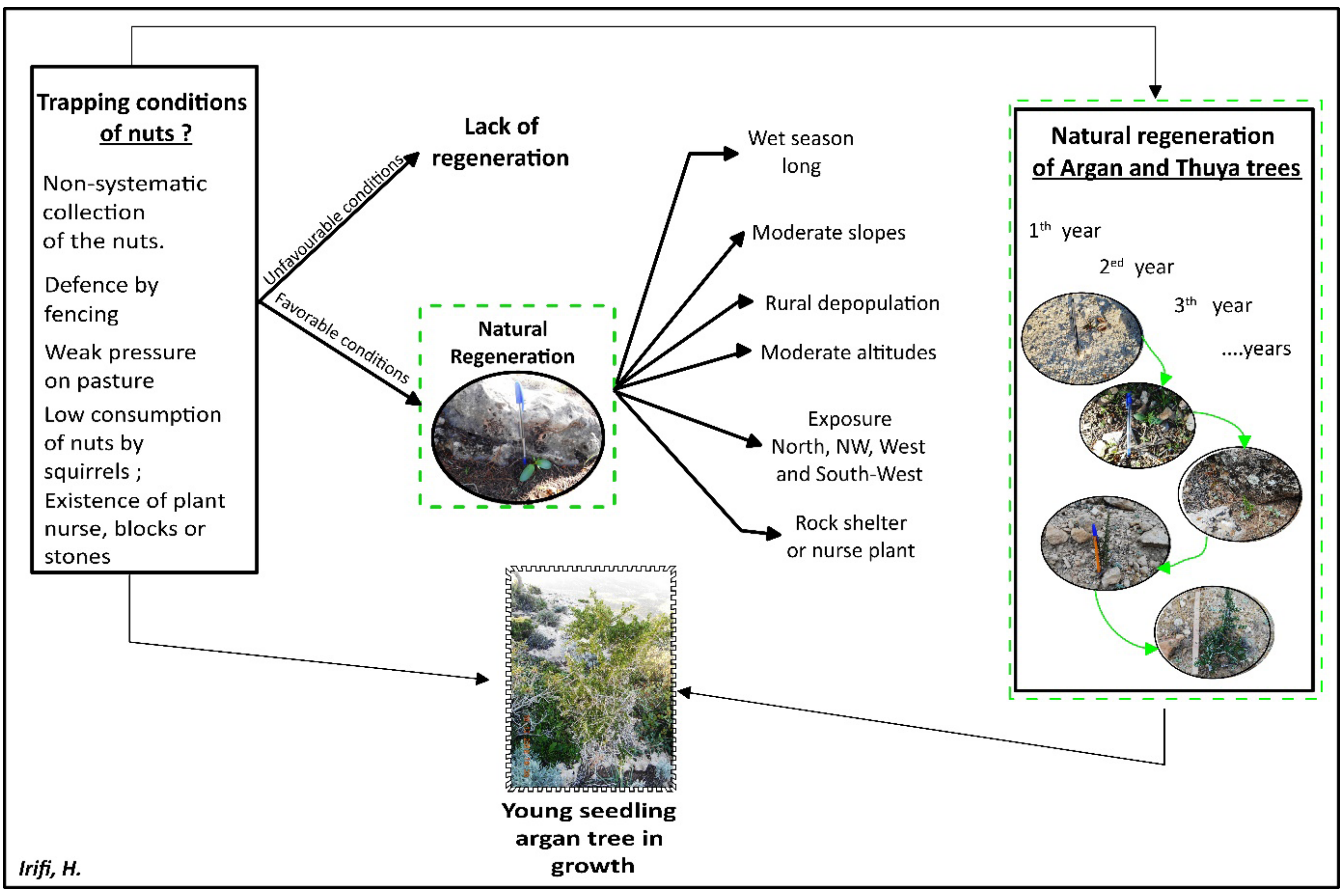

Figure 8. Conceptual model of natural regeneration of Argan and Thuya trees in the lower valley of Wadi Tamri. Source: own elaboration.

Climate is another important factor affecting the natural regeneration process. Affected by global climate change, precipitation in the lower valley of Wadi Tamri decreased to some extent, with an average rainfall of 300 mm. In addition to the seasonal irregularity of rainfall between the driest and wettest months, climate conditions are precarious in the sequence of dry years. The two diagrams (figure 9) clearly show the recurrence of dry years at the two stations in the watershed, the most severe of which follow one another from 1990 to 1994, and the longest is from 1999 to 2008, and the period from 2011 to 2013. Therefore, these are three severe dry periods preceded by the dry period of the 1980s. On the other hand, the wet years are very short (2 to 3 years on average) and generally record rainfall peaks with torrential character. In 1996, the station of Imouzzer, for example, in the southeast of the lower valley, recorded 1325.1 mm, of which 506.8 mm fell in January alone and 350 mm in December. In addition, the Tamri station has recorded three peaks in precipitation over 30 years, the most important of which was in 1996-1997, followed by a long dry period between 1998 and 2009, when rainfall was rarely above average. That confirms the affinity of the watershed to the Mediterranean climate, which is characterized by the concentration of rainfall in time and space in its original specificities. So, the rainfall rate trend to the negative records is dangerous for the natural regeneration of the whole forester landscape in the area. 146

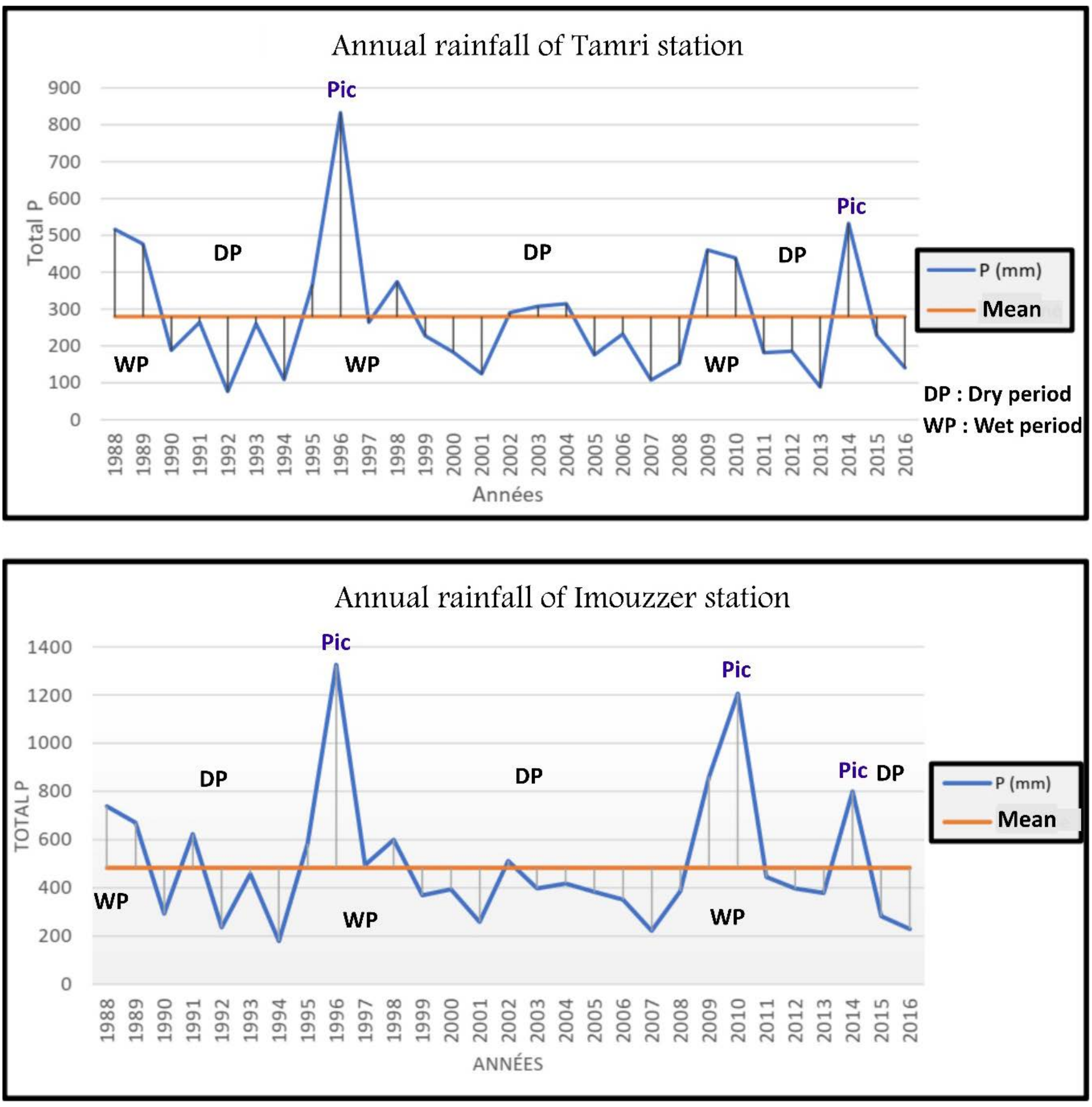

Figure 9. Diagrams of the annual rainfall recorded in two climatic stations.
WP: Wet Period, DP: Dry Period. Source: own elaboration based on *hydraulic basin agency Souss Massa, 2017*.

5. DISCUSSION

Our analysis indicates that the Argan and Thuya forest in the study area exhibits a low rate of natural regeneration. The findings confirm that both slope exposure, tree cover density, climatic conditions and human disturbance play significant roles in this phenomenon. This observation corresponds with the conclusions emphasized by Ait Hammou *et al.* (2018), indicating that the natural regeneration of Argan trees results from a combination of deforestation and tree loss. The lack or complete absence of Argan forest regeneration has been recognized over an extended period. The regeneration of a forest species includes several phases (fruiting of seedlings, then germination and development of seedlings), which depend closely on the surrounding factors (climatic, biotic, and edaphic factors). The importance of each of these factors is variable (Drapier, 1985). The installation of a young plant requires the germination of the seed and the survival of the seedling. That is the first and most vulnerable stage of natural regeneration (Baraloto, 2003) (figure. 10). In the argan forest of Ain Tamaloukt and Tamanar south, the production of nuts is influenced by drought, where we noticed that almost 90% of the plots record a weak to absent fruiting.

In this context of the dominance of drought and intense pressure on the tree and its flora, the natural regeneration of Argan and Thuya appears as a phenomenon reversing the evolutionary trends of this landscape, which knows an increased degradation. For natural regeneration, the nuts of Argan and Thuya must escape the systematic collection, the teeth of livestock and squirrels, and the dry period that often marks the area. If these conditions are fulfilled, and the seedling resists, and in reason to protect nursery plants or rocks, and in coincidence with rainy years, the young seedlings could thus resist and pass the stage where they are in danger. When the conditions for germination are not fulfilled, the seeds remain on the ground, where most of them rot (Baraloto, 2003). Also, the spatial distribution and abundance of productive trees and that of the shrub layer present favorable sites for seed dissemination, so they play a significant role in the probability of the establishment of young seedlings.

Ezzahiri and Belghazi (2000) found that in the Middle Atlas Mountains, the water balance and drought are limiting factors for the development of plantlets. Measurements made in the cedar grove showed that the water reserves of the surface horizons needed to be more robust to ensure the maintenance of the young seedlings. Like the cedar of the Atlas, the Argan tree is also very tolerant of drought and supports a slight water deficit. The resistance to drought, as mentioned by Ezzahiri and Belghazi (2000), lies in a deep and rapid root development, which explains its good colonizing power of superficial cracked soils (Ezzahiri *et al*., 2000; Grieu & Aussenac, 1988).

Figure 10. Photos depicting the natural regeneration of young Argan and Thuya seedlings in the study area. Source: cliche Irifi. a) Germination of an Argan nut, b) Argan seedling germinating in a biotope sheltered by a limestone block, c) Young semi-Argan tree germinating within a nurse plant (*Chamaecytisus albidus*), d) Growth of a young Thuya sapling surrounded by a protective plant (*Genista tricuspidata*).

"The regeneration of the Argan tree in natural forests is weak or absent because of systematic collection of nuts for oil extraction. Animals systematically browse young seedlings from seeds that escape harvest. Therefore, developing a national strategy for conserving this tree is essential. It must first be based on the establishment of a dissuasive and effective protection system to protect the tree from its aggressors" (El Finou *et al*., 2022). "It is a slow-growing tree, multi-branched from the base, that may be either shrub-like or a tree reaching 7–10 m in height" (Genin *et al*., 2017). In addition, in the Ait Baâmrane zone, Genin *et al.* (2017) "found that the regeneration we observed here seems to be only a knock-on effect of specific preservation of the soil because of the implantation of the prickly pear which does not require removal of the soil and the imposition of a drastic reduction of pastoral pressure to protect the orchards. The regeneration of the argan tree was not ex-ante the farmers' intention. Hence, the absence of grazing and improvement of soil fertility – perhaps associated with facilitation factors linked with interactions between plants – resulting from the proximity of prickly pear appeared to be the significant drivers for argan tree renewal". (Genin *et al.,* 2017). Finally, addressing the challenges posed by declining rainfall rates is essential for safeguarding the long-term health and vitality of the region's forests and ensuring their sustainable regeneration.

6. CONCLUSION

The natural regeneration observed in the forest landscape of the lower valley of Wadi Tamri result from the complex interaction of various landscape factors, including altitude, slope exposure, thermal conditions, rainfall patterns, as well as the nature of the slopes, substrate composition, and human activities. The geomorphological, climatic and orographic factors significantly influence natural regeneration, particularly evident in the relationship between slope exposure, altitude and seedlings cover density. In the Argan tree unit, more than 38 seedlings thrive on slopes facing West, North, North-West, and South-West, while the dominant Thuya forest unit harbors 78 young seedlings. Elevation factor plays a positive role in the regeneration of the dominant Thuya forest unit, particularly between 500 and 700 meters, where 122 young seedlings were recorded. Understanding the natural regeneration process of young Argan and Thuya seedlings is crucial for elucidating the dynamics of the current forest landscape. The maps Argania depict low rate of natural regeneration Argania spinosa, concentrated weakly in small areas, approximately 3.38%.

Furthermore, the dominant Thuya unit exhibit moderate and dynamic regeneration (13%), typically in areas with 3 to 5 young seedlings, often found in grazed areas and abandoned agricultural terraces. Dark green areas signify dynamic and moderate regeneration, which we called in this study "hotspot" of natural regeneration. The decline in rainfall rates presents a significant challenge to the natural regeneration processes occurring across the entire forest landscape in the region. This trend can have far-reaching implications for the ecosystem dynamics, affecting the growth and development of various tree and shrub species and altering the overall biodiversity of the area. As rainfall plays a crucial role in providing the necessary moisture for seed germination and seedling establishment, a decrease in precipitation levels can hinder the regeneration potential of forests, leading to ecosystem degradation and loss of habitat for numerous plant species.

Additionally, prolonged periods of low rainfall may exacerbate existing environmental pressures, such as soil erosion and desertification, further compromising the resilience and stability of the forest landscape. This landscape has undergone significant changes following rural abandonment, leading to a reduction in overgrazing pressure. Multiple interactive factors influence the establishment of natural regeneration of Argan and Thuya trees in the study area. Preserving and promoting such positive dynamics in the forest landscape present challenges that require appropriate technical and legislative measures. While it is impractical for the government to fence off the entire area or prohibit residents from utilizing forest resources, efforts should focus on raising awareness among the local population to alleviate pressure on forest resources.

Acknowledgements

At the end of this work, we would like to thank very warmly Mr. Achour Ahmed, Forest Engineer at the ANEF of Agadir, for his material and scientific support. And Ait Ettajer Ahmed. PhD student in Geography at the University Mohamed V of Rabat, for his accompaniment during our fieldwork.

Responsibilities and conflicts of interest

The authors undertake to disclose any existing or potential conflict of interest in relation to the publication of this article. Furthermore, the contributions of the two authors concerned are presented as follows:

- Irifi Hicham assumed the tasks of data collection through field work and the use of documents (maps, archive documents, satellite images, numerical data, statistical bases, etc.). He also ensured the development of the databases and the various figures as well as the interpretation and verification of the results in the field.
- Tribak Abdellatif provided direction and supervision of the work, analysis and interpretation of data, correction of the manuscript, validation of the results as well as the development of summaries in English and Spanish.

REFERENCES

Aafi, A. Sghir Taleb, M. & Fechtal, M. (2002). *Espèces remarquables de la flore du Maroc*. Centre National de la Recherche Forestière Rabat-Maroc. https://doi.org/10.33495/jacr_v6i1.18.110

Abouri, M. (2008). *Étude de la diversité floristique de la future aire protégée Cap-Ghir Tamri*.

[Mémoire de Master en Biologie, Université Ibn Zohr Agadir].

Ait Hammou, R., Harrouni, M.C., Cherifi, K., Hallouti A., & Daoud, S. (2018). Clonal selection of Argan trees (Argania spinosa L. Skeels) in the Admin forest, Agadir, Southwestern Morocco. *Journal of Agricultural and Crop Research, 6*(1), 7-18. https://doi:10.33495/jacrv6i1.12.110

Arroyo-Rodriguez, V., Melo, F., Martínez-Ramos, M., Bongers, F., Chaz-Don, R., Meave, J., & Tabarelli, M. (2016). Multiple successional pathways in human-modified tropical landscapes: New insights from forest succession, forest fragmentation and landscape ecology research. *Biol. Rev. Biological Reviews Cambridge Philosophical Society*, 1-15. https://doi:10.1111/brv.12231

Baraloto, Ch. (2003). Régénération forestière naturelle : de la graine à la jeune tige. *Rev. For. Fr. LV - numéro spécial, Description et Dynamique des Milieux Forestiers*, 179-187. https://doi.org/10.4267/2042/5770

Benabid, A. (2000). *Flore et écosystème du Maroc: Evaluation et préservation de la biodiversité*. Edition Ibis Press et Librairie et édition Kalila Wa Dimna.

Burrough, P.A., & McDonnell, R.A. (1998). *Principles of Geographical Information Systems*. Oxford University Press, Oxford. https://archive.org/details/principles-of-geographical-information-systems/mode/2up

Chakhchar, A., Ben Salah, I., El Kharrassi, Y., Filali-Maltouf, A., Cherkaoui, E, & Lamaou, M. (2022). Agro-Fruit-Forest Systems Based on Argan Tree in Morocco: A Review of Recent Results. *Frontiers in Plant Sciences, 12*, 13. https://doi.org/10.3389/fpls.2021.783615

De Waroux, Y.-P., & Lambin, E.-F. (2012). Monitoring degradation in arid and semi-arid forests and woodlands: The case of the argan woodlands (Morocco). *Applied Geography, 32*, 777-786. https://doi:10.1016/j.apgeog.2011.08.005

Drapier, J. (1985). Les Difficultés de Régénération Naturelle du Sapin (Abies Alba Mill.) Dans Les Vosges. *Étude Écologique, R.F.F. XXXVII* – 1. 45-55. https://doi.org/10.4267/2042/21785

El Finou, H., El-Khadir, I., & Hmouni, D. (2022). Effect of substrate, chemical treatment and microclimate on the regeneration of the Argan tree (*Argania spinosa.* L) by greenhouse cuttings. *Journal of Xi'an Shiyou University, Natural Science Edition*, 546-552. https://www.xisdxjxsu.asia/V18I09-64-1.pdf

El Ouahidi, A. (2008). *Étude morphosédimentaire des héritages pléistocènes et holocènes de la basse vallée de l'oued Tamri Maroc*. [Thèse, Université Nancy 2]. Emberger, L. (1925). Le domaine naturel de l'Arganier. *Bulletin de la Société Botanique de France, 72*(4), 770-774. https://doi.org/10.1080/00378941.1925.10832788

Ezzahiri, M., et Belghazi, B. (2000). Synthèse de quelques résultats sur la régénération naturelle du Cèdre de l'Atlas au Moyen Atlas (Maroc). *Sécheresse 2000, 11*(2), 79-84. https://www.jle.com/fr/revues/sec/e-docs/

Faouzi, H. (2011). L'Agdal dans la dynamique des systèmes agraires des arganeraies des Haha (Haut-Atlas Occidental, Maroc). *Études caribéennes*. https://doi.org/10.4000/etudescaribeennes.5569

Faouzi, H., Martin, J. (2014). Soutenabilité de l'arganeraie marocaine. Entre valorisation de l'huile d'argan et non régénération de l'arganier. *Confins, Revue franco-brésilienne*, (20). https://doi.org/10.4000/confins.8842

Genin, M., Alifriqui, M., Fakhech, A., Hafidi, M., Ouahmane, L., & Genin, D. (2017). *Back to forests in pre-Saharan Morocco? When prickly pear cultivation and traditional agropastoralism reduction promote argan tree regeneration. Silva Fennica 51*, 22. https://doi.org/10.14214/sf.1618

Glèlè Kakaï, R., Salako, V.K., & Lykke, A. M. (2016). Techniques D'échantillonnage En Étude De Végétation. *Annales des Sciences Agronomiques 20 - spécial Projet Undesert-UE*, 1-13. https://www.researchgate.net/publication/301210821

Grieu, Ph., & Aussenac, G. (1988). Croissance et développement du système racinaire de semis de trois espèces de conifères: Pseudotsuga menziesii, Pseudotsuga macrocarpa et Cedrus atlantica. *Ann. For. Sci. 45*, 117-124. https://doi.org/10.1051/forest:19880202

Ikechukwu, M.N., Ebinne, E., Idorenyin, U., & Raphael, N.I. (2017): Accuracy Assessment and Comparative Analysis of IDW, Spline and Kriging in Spatial Interpolation of Landform (Topography): An Experimental Study. *Journal of Geographic Information System 9*, 354-371. https://doi.org/10.4236/jgis.2017.93022

Irifi, H., Tribak, A., & Achour, A. (2017). Dynamique du paysage forestier de l'Arganeraie Caractéristiques, évolution et valorisation: Cas de l'Arganeraie de la forêt d'Ain Tamaloukt, Commune territoriale de Tamri, Maroc. In *Acte de congrès international de l'Arganier* (pp. 63-69). https://www.congresarganier.com/pdf/Cia2017/ActesCongres2017.pdf

Irifi, H., Tribak, A., & Achour, A. (2020). Paysages naturels dans la basse vallée de l'oued Tamri (Maroc): proposition de l'approche paysagère pour une valorisation touristique. *Geography notebooks Vol. 3. Tourism, Representations and Preservation of Territories* (pp. 15-36). https://doi.org/10.7358/gn-2020-001-irif

Irifi, H., & Tribak, A. (2021). Diversité Floristique et Paysagère du Cours d'eau de la Basse Vallée de l'oued Tamri (Haut Atlas Atlantique, Maroc). *Geomaghreb 17*, 13-30. https://revues.imist.ma/index.php/Geomaghreb/article/view/36972/19141

Irifi, H. (2023). *Mountains Landscape Dynamics: Parameters, Impacts, and Valorization. The case of the lower valley of Wadi Tamri (Atlantic Atlas)*. [PhD thesis, Sidi Mohamed Ben Abdellah Saîs Fès University]. (In French).

Laaribya, S. (2021). Multiple Spatial Changes In The Argan Ecosystem-(Argania spinosa (L.) Skeels) -Case Study(Morocco). *Scientific Bulletin of the Kazakh Agrotechnical*, In. *S. Seifullina (interdisciplinary), 2*(109). https://bulletinofscience.kazatu.edu.kz/index.php/bulletinofscience/article/view/790/728

Lefhaili, A. (2020). *FAO forest resources assessment: Morocco country report*. FAO.

Le Floc'h, E., Nedjraoui, A., Hirche, A., Boughani, A., Salamani, M., Abdelrazik, M., Ouled Belgacem, A., Tbib, A., Ramdane, A., Aafi, A., Taleb, M., Dembele, F., Karembe, M., Mahamane, A., Wélé, A., Ba, M., Ichaou, A., Ouedraogo, S., Jauffret, S., Long, G., d'Herbès, J-M., Loireau, M., Desconnet, J-C., Delanoë, O., & de Montmollin, B. (2008). *Guide méthodologique pour l'étude et le suivi de la flore et de la végétation.* Collection Roselt/OSS-Contribution Technique n° 1, Tunis, 175 p. https://www.researchgate.net/publication/269871859_Guide_methodologique_pour_l'etude_et_le_suivi_de_la_flore_et_de_la_vegetation

McGregor, H. V., Dupont, L., Stuut, J. B. W., & Kuhlmann, H. (2009). Vegetation change, goats, and religion: a 2000-year history of land use in southern Morocco. *Quat. Sci. Rev. 28*, 1434–1448. https://doi:10.1016/j.quascirev.2009.02.012

Mitas, L., & Mitasova, H. (2005). Spatial Interpolation. In P.A. Longley. M.F. Goodchild. D.J. Maguire & D.W. Rhind (Eds.) *Geographic Information Systems: Principles, Techniques, Management and Applications*, 2nd Edition, Vol. 1, Part 2, Chapter 34. www.geos.ed.ac.uk/~gisteac/gis_book_abridged/

Mohammed, Y. (1994). *Méthodes de mesure quantitatives de la végétation. Cours d'aménagement des ressources naturelles : initiation à l'étude quantitative et qualitative de la végétation.* Institut Agronomique et Vétérinaire Hassan II.

Peltier, J.-P. (1982). *La végétation du bassin versant de l'oued Souss, Maroc*. [Thèse de doctorat. Université de Grenoble].

Zunzunegui, M., Jáuregui, J., Ain-Lhout, F., Boutaled, S., Álvarez-Cansino, L., & Esquivias, M. (2013). Germination Success and Seedling Development of Argania spinosa under Different Climatic Conditions and Browsing Intensity. *Natural Product Communications 8*(1), 15-20. https://doi.org/10.1177/1934578X1300800104