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CONTRIBUTION OF GEOMATICS IN THE MANAGEMENT OF THE FOREST MASSIF OF TELAGH, DHAYA MOUNTAINS (WESTERN ALGERIA)

by

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Abstract

The progressive deterioration of the forest cover of the Dhaya Mountains is considered a principal environmental problem in Algeria. The forest management which is based on conventional methods seems unable to follow the cadence of the degradation of forests, especially, in arid and semi-arid zones subjected for many years to hard climatic and anthropogenic pressures. At present, the public policy aims to develop approaches that capitalize on information and data, involving the local populations. Hence, geomatics (G.I.S and digital geographic information) imposes itself in a privileged place, its inputs allowing better management and processing of local information and its contribution to the management of natural environments.

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The aim of this study is to illustrate the importance of geomatics in forest management and to provide forest managers with a decisive support tool in the Dhaya Mountains.

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1. INTRODUCTION

In Algeria, over the past few decades, the forestry policies have not reached a sustainable management because they have not sufficiently integrated the human dimension, and thus have not prevented the evolution of socio-economic issues around forests. Since the Rio Summit held in 1992, taking into consideration the evolution of the forestry issue, some non-binding forestry principles were adopted by the United Nations Commission for Environment and Development (UNCED). In this line, a concerted management approach pays particular attention to the concepts of partnership and participation (BENZYANE et al., 2002).

For a country like Algeria, where agro-pastoral traditions are present, the concerted management between the different parties involved in the forests, such as foresters, herders and villagers, is essential to optimize agricultural and forestry resources (BAAR & ANDRÉ, 1995).

GIS is a powerful tool that can be used to perform a variety of quantitative analysis. It is the "glue" that holds all the data together and which allows the display, analysis and measurement of the information coming from different sources (GOODCHILD et al., 1999). GIS can be used to develop useful models to try to find new resources based on an analysis of the relationship between environmental and cultural data (crossing layers, buffer zone, arithmetic and logic operation on data in raster format, etc.) (LO & YEUNG, 2003).

Remote sensing (RS) and geographic information system (GIS) technologies will indeed play a crucial role in the development of effective decision support systems or expert systems for the sustainable development and management of vital but shrinking water resources (LO & YEUNG, 2003, CHAUVIN, 2004, MOUISSA et al., 2018, GUERINE & HADJADJ, 2019, GUERINE et al., 2020). The objective of this article is to

provide forest managers with a decision-support tool in order to properly manage the forest massif of Telagh.

2. MATERIALS AND METHODS

2.1 Presentation of the study area

Located in the south of the wilaya of Sidi Bel Abbes (Western Algeria), the forest of Touazizine-Takrouma (forest massif of Telagh) is located in the southern Dhaya Mountains (Western Tell) and borders the high steppe plains (FIG. 1).
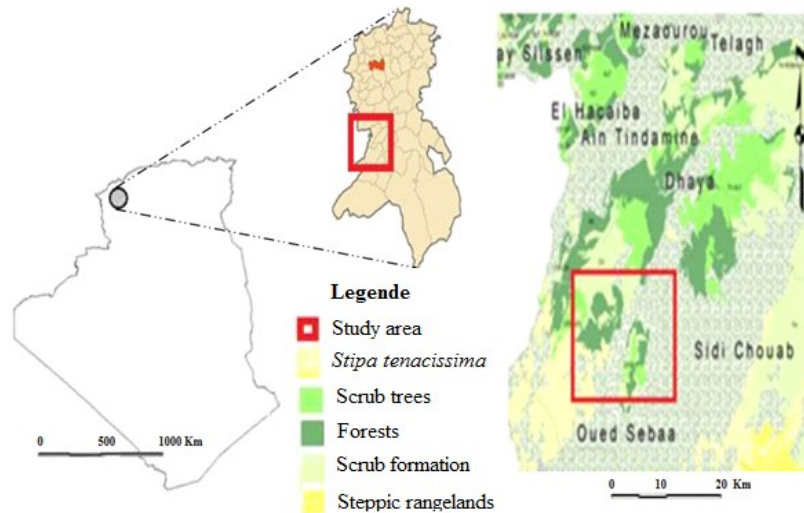

FIG. 1 - Localization map of the study area

The study area is composed of two State forests:
State forest of Touazizine : it extends to the east and south of the valley of the Mekerra and occupies the Djebel Marhoum which it entirely covers, it is contiguous with the forest of Toumiet in the North and is separated from the forest of Takrouma by the village of Dhaya and the national road n° 13 which connects it to the town of Telagh, distant of 15 Km, and Ras El Ma which is situated at 30 Km. The planimetry of the inventory of the ONTF (1980), gave an area of 12,980 ha

(without including the arboretum). The forest belongs to two administrative divisions, the rural communes of Oued Sebaa and Dhaya.

State forest of Takrouma : it is a kind of plateau crossed by the wilaya path leading from Dhaya to Sidi Chaib. It is located to the east of the forest of Touazizine and limited on the south by the steppe. The planimetry gives an area of 3265 ha. Administratively, it is located on the territory of the communes of Dhaya and Sidi Chaib.

The structure of the Dhaya Mountains is constituted by two parallel anticlines of southwest-northeast orientation. The average altitude is between 1200 and 1300 m. with a highest elevation of 1414 m. at Djebel Boulhaf.

According to the work of KADIK (1983), the forest of Touazizine-Takrouma is included in the zone where the Mediterranean climate is semiarid with cold winters. The soils that are poor in organic substance and rich in sand are formed on hard limestone and are vulnerable. In case of degradation of the vegetation, intense erosion reaches a sterile bedrock. Aleppo pine (*Pinus halepensis*) is the most abundant tree, associated with green oak (*Quercus ilex*) and thuya (*Tetraclinis articulata*). The most abundant species of the matorral are *Juniperus oxycedrus, Calicotome spinosa, Rosmarinus tournefortii, Genista spartioides, Chamaerops humilis, Globularia alypum, Stipa tenacissima, Pistacia lentiscus* and *Phillyrea angustifolia*.

The biological balance of the forest as a whole cannot be dissociated from its economic and social environment. The evaluation and development of this heritage cannot be conceived in a purely ecological context if the stability of the ecosystem is influenced by socio-economic aspects.

The population living around the forested area of this study is 39,028 inhabitants. BENABDELI (1996) notes, "Because of their geographical location, the Dhaya Mountains are exposed

to a human concentration whose activity is almost a permanent use of forest formations. Trails, farms and fires are the most significant aggression and their impact on forest ecosystems is not negligible. Livestock systems practiced around the forest are of considerable importance to the local economy, 60% of the total population finds its source of income in livestock farming, particularly of sheep. It takes economic and ecological dimensions beyond the framework of the forest massif."

2.2 Methodological approach

The general methodology is based on an approach combining the GIS, forest inventory results, and the socio-participatory diagnosis. These components take part in the study following some successive steps, as shown in the diagram of the methodology (FIG. 2). Results will be produced as a result of each step.

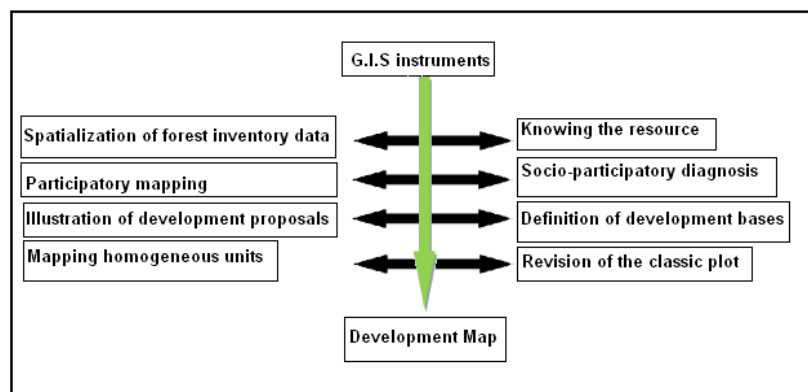**FIG. 2 -** Flow chart illustrating the approach followed for the study

2.2.1 Step 1 : Knowing the resource

The data used for the characterization of the vegetation in the study area are derived from the results of the field inventory of the two forests comprising the forest massif under study carried out by ONTF (1980), phytosociological and phytoecological studies of BENABDELI (1996) in the Dhaya

Mountains and the population map (established by photo-interpretation) carried out by BNEDER (2008) as part of the national forest inventory. Many studies provide results without any evaluation of their quality (CONGALTON, 1991). However, the validation step is essential to validate the results, to ensure a relevant scientific use of the maps produced, and to be a support for the improvement of the methods of treatment (KLEINN, 2002).

Due to the great heterogeneity of both developmental stages and densities, the traditional methods of evaluation of woody resources for stands that have been managed for a long time are not always valid. In this case, a stratified random sampling allowed the installation of 30 sampling plots. The general morphology of the stand led us to sit plots of 4 square ares (20 m x 20 m). The information used for the spatialization of the inventory data is essentially of the cartographic type supplemented by field observations. Three thematic maps, relating to relief, soils, phytosociology, have been produced. All the processing of the map data has been done with MapInfo software. Topoclimatic observations - mean slope, exposure, altitude, and soil data (soil type, soil depth, and humus abundance) were determined by management units in the plot description (ONTF, 1980). Each of these data has been digitized in a GIS and each map unit refers to an alphanumeric record containing the parameters that describe the unit.

2.2.2 Step 2 : Participatory observation

Mapping does not only provide information and physical characteristics, but can also reveal information about the ecological and socio-economic aspects of the sector and the community concerned by the assessment (CHORFI, 2008). The approach proposed for participatory observation based on participatory mapping is inspired by the work of MATHER et al. (1998). Our work was undertaken in the main villages in the peri-forest area. Topographic maps of the study area were scanned and then printed (A1) on a large scale, showing the

forest massif and making the neighboring village perimeters clearly visible for about ten people to view them comfortably.

Using transparent paper overlay on topographic maps; the participants (regardless of their level or social category) trace using the markers " the participatory map. ". This step contributes in a simplistic way to plotting the areas of the forestry problem. Participatory maps were scanned, geographically corrected and digitized with the help of G.I.S.

2.2.3 Step 3 : Revision of the classic forest management units

The sole objective of wood production is no longer able to satisfy the current needs of the society for which some principal functions are equally essential (NIVELLE, 1990). The studies of forest management of the forest massif of Touazizine-Takrouma, initiated by the ONTF (1980), allowed the elaboration of a classic topographical plot, the limits being the characteristics of relief and the network of infrastructures. The development of the forest management units is a fundamental step in the analysis of the forest stands (BOUSSON et al., 1998, RONDEUX, 2002). Moreover, the potential of the environment given the constraints and socio-economic needs leads to a multifunctional zoning of the forest area. The objectives for each area identified determine the forestry treatments to be applied and the priority in equipment implementation.

2.2.3.1 Necessary data

The necessary multi-objective development data include the soil surveys, the topo-climatic observations of the plots described by the ONTF (1980), the results of the forest inventory work carried out by the BNEDER (2007). Those data are to be updated and finally the data from the socio-participatory diagnosis integrated.

2.2.3.2 Means and cartographic materials

The graphic components of our GIS are based on the following different reports :
- Topographic maps (n ° 330 and n ° 331, respectively of 'Djebel Ouargla' and 'Dhaya'), scale 1/50 000, 1979 edition with Lambert North Algeria projection .
- Digital elevation Model (DEM) produced at a spatial resolution of 30m by interpolation of contour lines digitized on INC topographic maps to 1/20 000.
- Forest management units of the study area, which were established at 1/10 000 by the ONTF (1980). The plan was scanned in format (A0), then rectified and georeferenced using MapInfo Ver.08 software (FIG. 3).

Graphic information can be linked to tables (tabular information) through identifiers. For example, in FIG.3, identifiers are management unit numbers and the table, that can be part of a general database, holds the forest management informations.
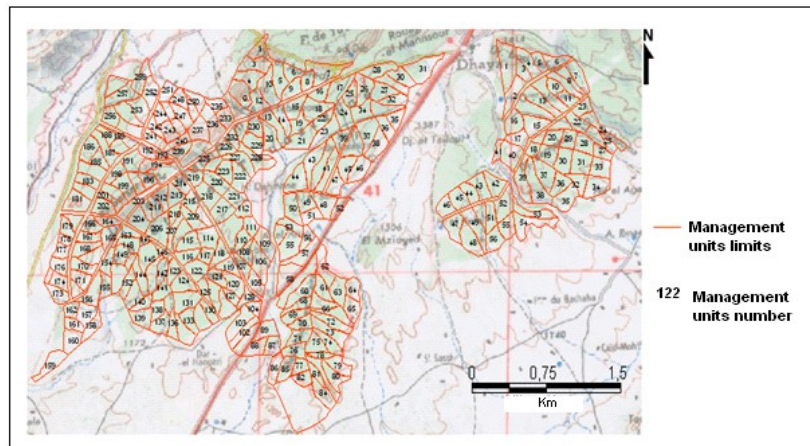

FIG. 3 - Map of classic forest management units

2.2.3.3 Creating tables

In the MapInfo software, the basic object is the table. Any information layer is associated with one or more tables. Creating

tables within MapInfo is very simple. The software offers interactive tools for creating tables similar to the traditional tools found in most software. Each developed unit will give rise to a table. We have created the following tables in MapInfo : Management Units, Series, Forest, and Forest Massif. The database of the descriptive records of management units was entered by entry. According to the figure, all the data will form the plots, and in turn the plots will constitute the forest massif of our study. The database of the descriptive plot sheets was entered by entry.

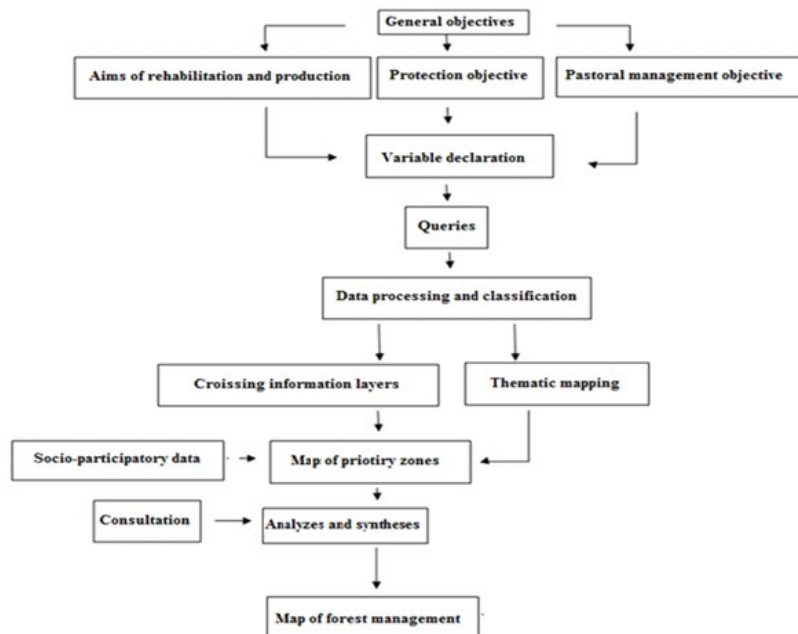## 2.2.3.4 Classification of management units

FIG. 4 - Simplified diagram of the organigram of the developed program

The application developed for classifying management units and identifying priority zones exploits the database created in the management units table, and allows the realization of spatial requests and the elaboration of thematic maps (FIG. 4).

The classification procedure takes into account a certain number of criteria relating to the homogeneity of the management

units in relation to the objectives chosen to translate the various functions to be involved in the development of the forest management.

3. RESULTS AND DISCUSSION

3.1 Spatialisation of inventory data

The information obtained for each management unit was entered into the geographic database of our GIS. This for example allows mapping the spatial distribution of soil quality (FIG. 5, 6, 7 and 8) of the forest massif. Such maps will make it possible to provide justifications for future reforestation that takes into account species autoecology, since according to AUBERT (1978), the composition of the surface horizon, especially in the Mediterranean region, plays an important role for the vegetation.
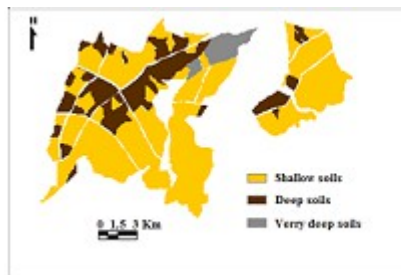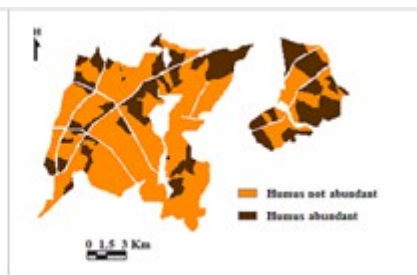

FIG. 5 - Soil Classes
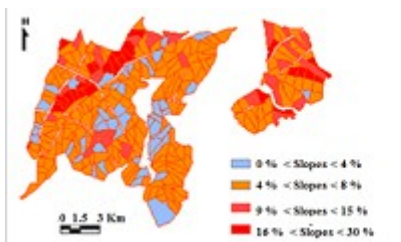
FIG. 6 - Distribution of humus according to its abundance

FIG. 7 - Slope classes
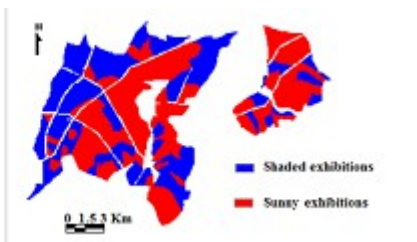
FIG. 8 – Nature of exposures

3.2 Map of the ecological sites for the study area

According to BAAR & ANDRÉ (1995), "The study of the potentiality of the ecological sites, under the pedological aspects and climatic topo on the one hand and under the phytosociological aspects on the other hand, is the basis of the reflection delimiting the zone of production". The characterization of forest zones in the forest massif is defined by adding phytosociological data to the pedological, and topographical ones. Each ecological site is defined by its homogeneity for the recorded parameters. Eighteen (18) ecological sites have been defined and are recorded in Table 1 and mapped in Figure 9, while Table 2 gives the major types of vegetation.

FIG. 9 - Maps of the ecological sites of the Touazizine-Takrouma forest massif

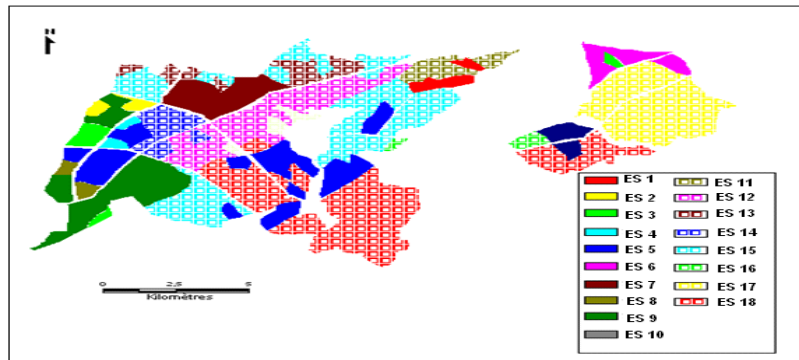**Table 1:** Main characteristics of the ecological sites of the forest massif

Ecological sites (ES)	Area		Phytosociological characteristics		Edaphic characteristics		Topographic characteristics	
	(Ha)	(%)	Vegetal formation	Density	Substrate	Soil depth	Slope	Exposure
ES 01	151.4	0.9	Aleppo pine forest	strong	calcareous	very deep	low	shaded slopes
ES 02	121.7	0.7	Aleppo pine forest	strong	calcareous	deep	low	shaded slopes
ES 03	232.2	01	Aleppo pine and green oak forest	low	calcareous	deep	low	shaded slopes
ES 04	84.3	0.5	Aleppo pine and green oak forest	low	calcareous	deep	moderate	sunny slopes
ES 05	1520.4	09	Aleppo pine and green oak forest	low	calcareous	shallow	low	sunny slopes
ES 06	402.5	02.5	Aleppo pine and green oak forest	low	calcareous	shallow	smooth	sunny slopes
ES 07	685	04	Aleppo pine and green oak forest	low	calcareous	shallow	moderate	shaded slopes
ES 08	120.4	0.7	Aleppo pine forest with *Stipa tenacissima*	low	calcareous	deep	low	shaded slopes
ES 09	1252.1	07.5	Aleppo pine forest with *Stipa tenacissima*	low	calcareous	shallow	low	shaded slopes
ES 10	234.3	01	Aleppo pine forest with *Stipa tenacissima*	low	calcareous	shallow	smooth	sunny slopes
ES 11	202.9	0.1	Matorral of *Pinus halepensis*, *Quercus ilex* and *Juniperus oxycedrus*	low	calcareous	very deep	low	shaded slopes
ES 12	487.3	03	Matorral of *Pinus halepensis*, *Quercus ilex* and *Juniperus oxycedrus*	low	calcareous	deep	low	sunny slopes
ES 13	1424.3	08	Matorral of *Pinus halepensis*, *Quercus ilex* and *Juniperus oxycedrus*	low	calcareous	deep	smooth	shaded slopes
ES 14	463.2	03	Matorral of *Pinus halepensis*, *Quercus ilex* and *Juniperus oxycedrus*	low	calcareous	deep	moderate	shaded slopes
ES 15	2487.9	15	Matorral of *Pinus halepensis*, *Quercus ilex* and *Juniperus oxycedrus*	low	calcareous	shallow	low	sunny slopes
ES 16	129.7	0.7	Matorral of *Rosemarinus tournefortii,Stipa tenacissima* and *Calycotome spinosa*	low	calcareous	deep	low	sunny slopes
ES 17	2948.4	18	Matorral of *Rosemarinus tournefortii,Stipa tenacissima* and *Calycotome spinosa*	low	calcareous	shallow	low	sunny slopes
ES 18	1793.4	11	Matorral of *Rosemarinus tournefortii, Stipa tenacissima* and *Calycotome spinosa*	low	calcareous	shallow	smooth	sunny slopes

Table 2 : Major types of vegetation and their area

Type of vegetation	Surface (ha)	Surface (%)
Forests		
Aleppo pine forest	4803,56	30
Degraded forests (Matorral)		
Matorral of *Pinus halepensis,Quercus ilex* and *Juniperus oxycedrus*	5065,74	31
Matorral of *Rosemarinus tournefortii, Stipa tenacissima* and *Calycotome spinosa*	4871,55	30
Bare land	1504,15	09
Total	16245	100

The percentage of each vegetation type shows a predominance of the deteriorated formations that, together with the bare land, occupies 70% of the total area of the forest massif. This observation makes it possible to argue that the vegetation cover subjected to constant anthropozoogenic pressure evolves towards stages of degradation. This situation must be controlled by sylvicultural and development interventions.

Photo 1. Matorral of rosemary, alfa and Calycotome (**Dahmani, 2019**)

3.2.1 Interests of the ecological sites map

The management of forest ecosystems in Algeria cannot be done without taking account of ecological conditions that impose a mosaic of formations difficult to manage without coming to the level of homogeneous entities (HADJADJ & LETREUCH-BELAROUCI, 2015, HADJADJ, 2017, HADJADJ & LETREUCH-BELAROUCI, 2018). Those homogeneous sets resulting from the stationary conditions make it possible to identify natural management entities. After a profound knowledge of these units, the techniques of development can be generalized without exception throughout the surface. The forester can thus base his management on the assumption of the same behavior for the species growing there.

3.3 Socio-participatory mapping

Four homogeneous spatial units (HSU) for forestry based on species and their use, right of use, the abundance of the resource and level of production of local agriculture were identified (Table 3).

Table 3 : Land use for the four Homogeneous Spatial Units

	HSU 1		HSU 2		HSU 3		HSU 4	
Ethnic Fraction	Ouled Balaghfouaga		Ouled Balaghthata		Ouled Faid		BéniMathar	
Area	18 700 ha	100%	9 070 ha	100%	5 519 ha	100%	7 708 ha	100%
Forest	8 794 ha	47%	2 102 ha	23%	3 000 ha	54%	2 343 ha	30%
Agricultur e	5 400 ha	29%	6 784 ha	74%	2 450 ha	44%	2 123 ha	27%
Steppe	4 424 ha	23%	0 ha	0%	0ha	0%	2 905 ha	37%
Urban	82 ha	01%	184 ha	03%	61 ha	02%	336 ha	06%

The system of agro-sylvo-pastoral production extends over the whole massif south of the mountains of Dhaya, where the majority of the local population drives their sheep, cattle and goats. The forest massif plays a role in animal feed (mountain alfa, green oak and juniper) during the winter. The purchase of fodder (with an excessive cost) and the system of transhumance (forest-steppe massifs) can complement this contribution, but do

not replace it. The forest area is exploited by the riparian populations for which it constitutes a source of income. According to the respondents, the pressure exerted on the forest massif is the main cause of its regression. It seems important to consider that the pressure of grazing explains a regressive dynamic through the limitation of regeneration.

3.3.1 Benefits of participatory mapping

Mapping does not only provide information on physical characteristics, but can also reveal information about the ecological and socio-economic aspects of the sector and the community concerned by the assessment (CHORFI, 2008). Mapping is generally seen by local communities as a mean of restoration (JACKSON et al., 1994). The participatory map is used to structure the communication between different stakeholders (riparian populations, forest administrations, local authorities), to define the ethno-spatial organization and to identify issues to be examined in concert to define the location of activities that will be undertaken under the development plan.
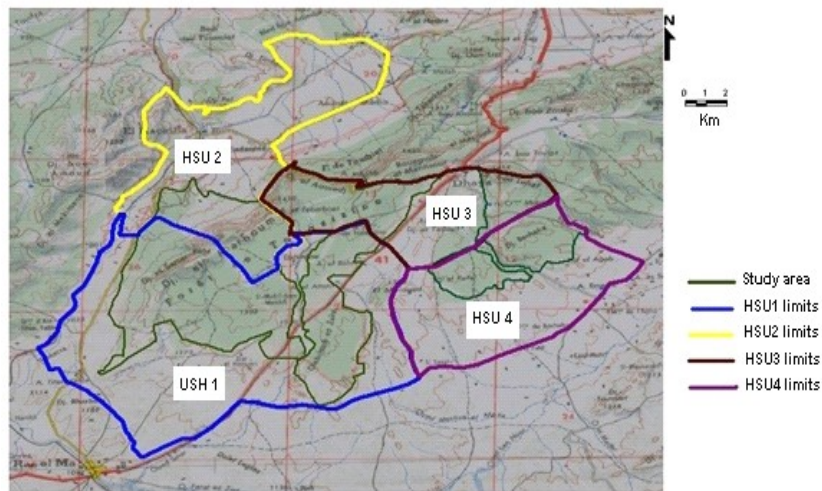

FIG. 10 - Map of Homogeneous Spatial Units reproduced from the Telagh I.N.C background map on which the boundaries have been superposed by scanning.

3.4 Map of priority areas: Development orientation map

The definition of management objectives as a whole requires in-depth knowledge, mainly of the socio-economic and ecological contexts. It takes into account the priority objectives. The latter require complementary data, which relate to the nature of the species and the station ability to be protected against forest fires, the quality of soil conservation, the sylvopastoralism and the other uses of the forest massif.

These data are necessary in order to carry out the characterization of the plots and to delimit the different zones : rehabilitation, soil conservation, protection of the massif against fire and sylvopastoral balance. In order to define the different priority zones, an instruction has been requested from the GIS to resume on a new map the boundaries of the priority zones whose delimitation is deduced from the combination of the two maps of the ecologically homogeneous stations and of HSU.

In this case, the priority zones map (FIG. 11), in its simplest form, comprises three zones : the production priority area (5400 ha, or 33% of the total area of the massif), the priority area for protection against fire and erosion (9870 ha, or 60% of the surface of the massif) and the sylvopastoral zone (975 ha, or 7% of the massif). This map is a synoptic representation of the future objectives of forest management.
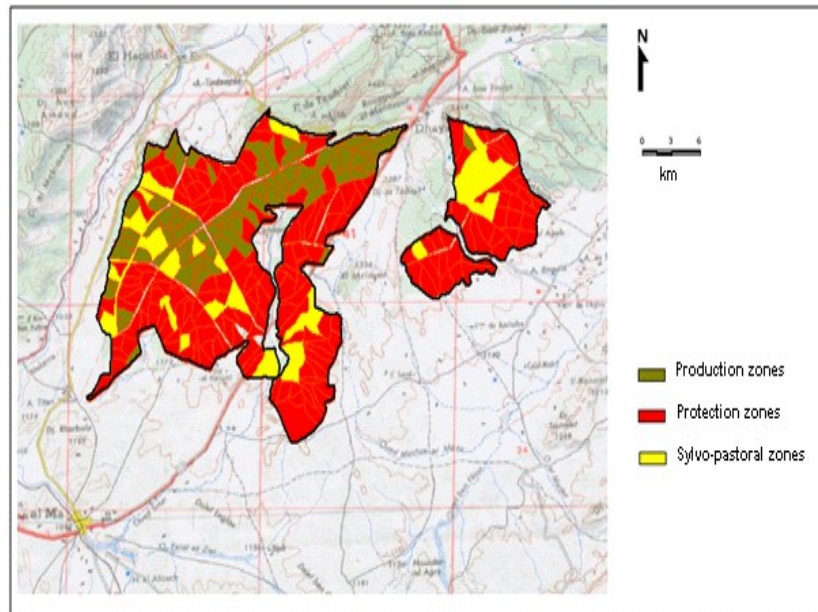
FIG. 11 - Map of priority areas: of the Touazizine-Takrouma forest massif

3.4.1 Interests of the priority areas map

From the priority areas map, the manager can easily make decisions about investment priorities. The GIS can automatically select from one map one or more information and create thematic maps. The manager will orientate by zone :
- Reforestation investments in areas where production factors are homogeneous.
- The different sylvicultural practices and the introduction of species adapted to the conditions of the region studied.
- Investment for fire fighting and water and soil conservation.
- Pasture management (grazing period and animal load) taking into account the productive capacity of the vegetation.

Geomatics by mapping is an interesting dialogue tool between decision-makers and stakeholders involved in the forest massif, namely the local population, the various users, the public authorities and the manager. Thanks to the ease of modification and modeling of which GIS are capable, the development

proposals expressed in cartographic form can easily be updated and adapted, according to the needs of the users of the massif.

4. CONCLUSION

The approach followed in this study, starting from a thorough knowledge of the socio-economic and ecological context with the application of geomatics makes possible interesting advances in forest management. The creation of a computerized data bank is for the manager a fundamental indicator of the factors to be taken into account per plot in choosing the species for reforestation, the treatments to be applied and the investments to be made. Finally it is a tool of effective social dialogue.

5. ACKNOWLEDGEMENTS

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