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Geology Department

Integrating Sentinel data and PAPCAR model to map water erosion using ArcGIS Pro: Case of Beni Boufrah watershed, Morocco

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Outline

- Introduction
- Presentation of the study area
- Presentation of the work methodology
- Study of the potential soil degradation at Beni Boufrah watershed
- Conclusion

INTRODUCTION

Soil degradation is a phenomenon that has worsened as a result of the effect:

- **natural factors** (precipitation, wind, runoff, etc.),
- harmful **anthropogenic actions** (overgrazing, overexploitation of forest resources, mismanaged irrigation, urbanization, etc.).
- Depending on their characteristics (topography, composition, vegetation cover, land use), soils offer varying degrees of resistance.

INTRODUCTION

The major causes of land degradation

- Water and wind erosion of soils
- Urbanization
- Deforestation, overexploitation and overgrazing
- The loss of soil biodiversity

INTRODUCTION

The effects of soil degradation

- *On the environmental level* :

- The loss of soil fertility;
- Decrease in water retention capacity;
- Disruption of gas and nutrient cycles

- *On the socio-economic level* :

Reducing agricultural soil productivity .

It can also affect the health of the population.

INTRODUCTION

Land degradation in Morocco

In Morocco, more than 40% of the land is threatened by water erosion :

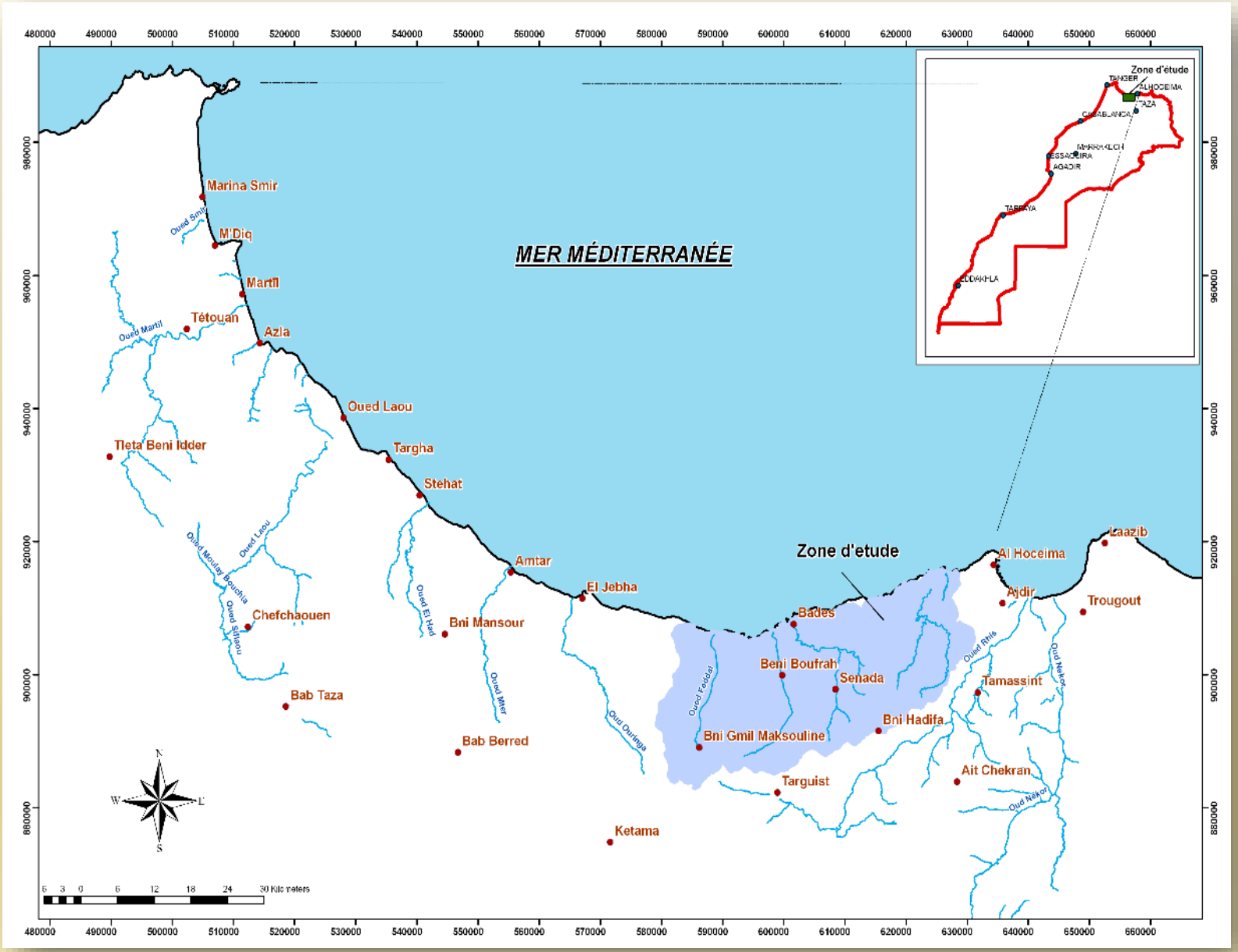
up to 500 t/ha/year

This situation is mainly due to:

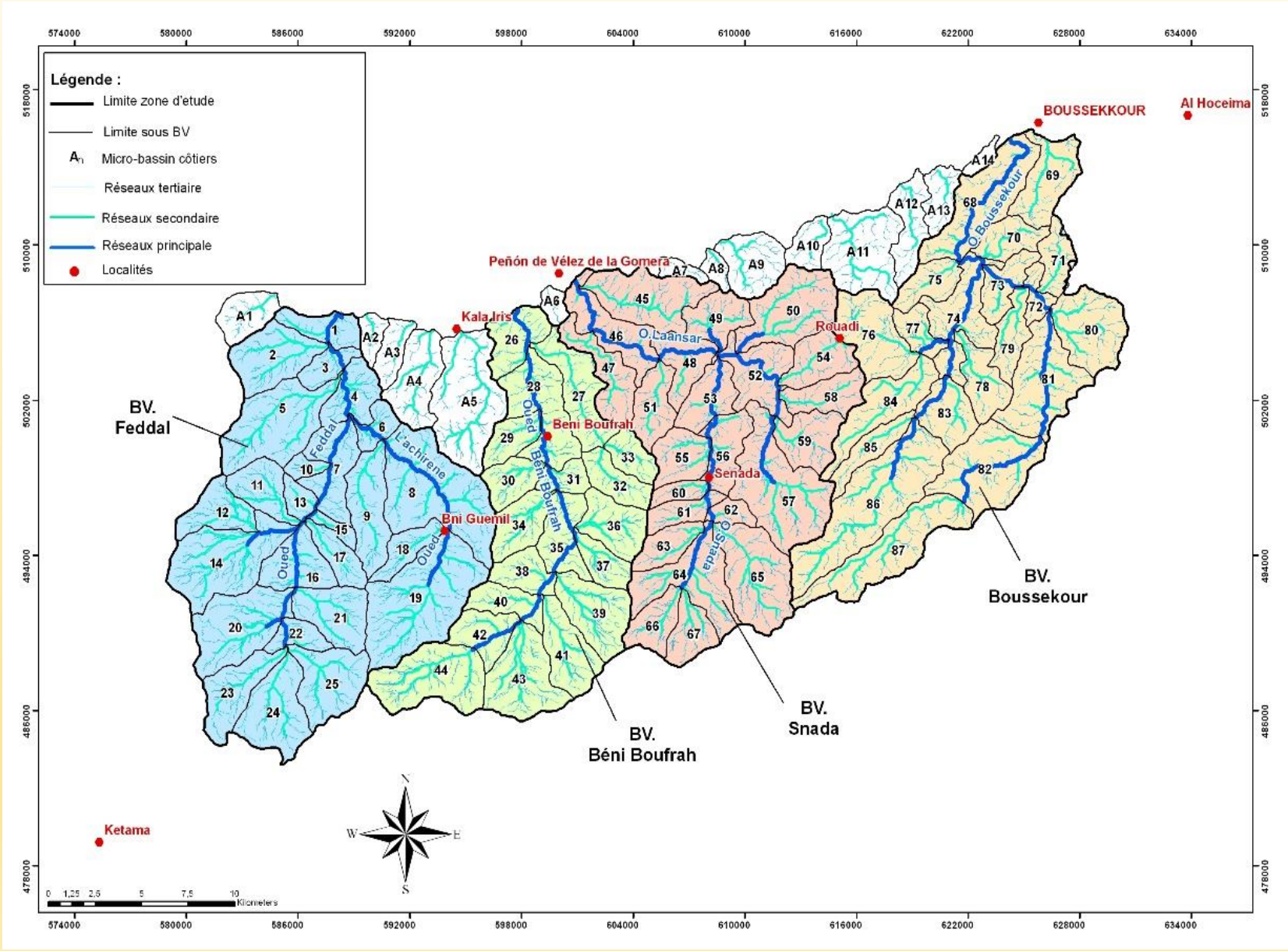
- Climate regime: rainfall/dry spells
- Presence of highly erodible soils
- Rough terrain

PRESENTATION OF THE STUDY AREA

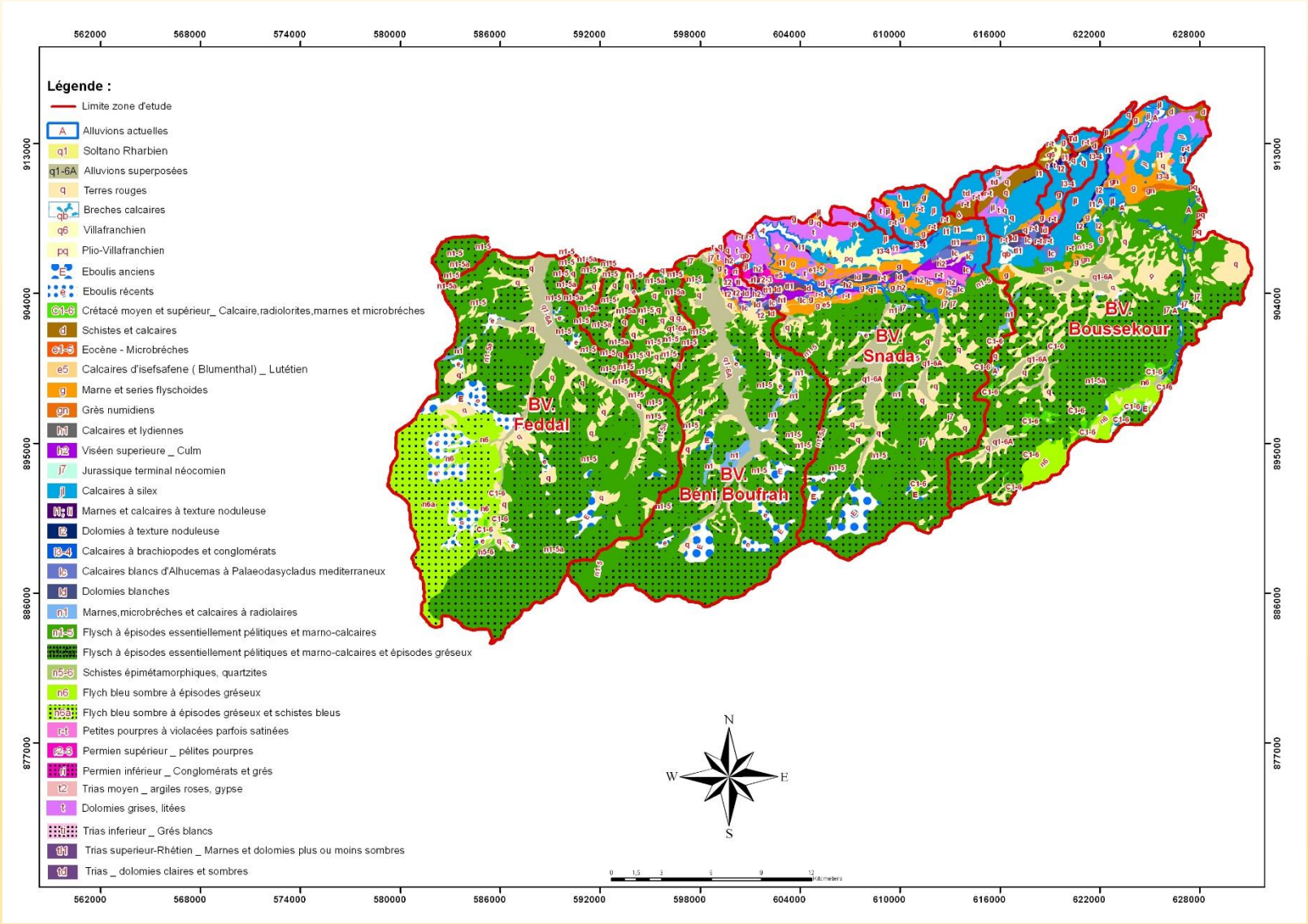
Geographical situation



Sub watershed map



Geology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Légende :
Limite zone d'etude
A Alluvions actuelles
q1 Soltano Rharbien
q1-6A Alluvions superposées
q Terres rouges
qb Breches calcaires
q6 Villafranchien
pq Plio-Villafranchien
E Eboulis anciens
E Eboulis récents
C1-6 Crétacé moyen et supérieur_ Calcaire,radiolorites,marnes et microbréches
d Schistes et calcaires
e1-5 Eocène - Microbréches
e5 Calcaires d'isefsafene (Blumenthal) _ Lutétien
g Marne et series flyschoides
gn Grès numidiens
ln1 Calcaires et lydiennes
h2 Viséen superieure _ Culm
j7 Jurassique terminal néocomien
j Calcaires à silex
N2 M Marnes et calcaires à texture noduleuse
l2 Dolomies à texture noduleuse
l3-4 Calcaires à brachiopodes et conglomérats
ls Calcaires blancs d'Alhucemas à Palaeodasycladus mediterraneux
lj Dolomies blanches
n1 Marnes,microbréches et calcaires à radiolaires
n1-5 Flysch à épisodes essentiellement pélitiques et marno-calcaires
Flysch à épisodes essentiellement pélitiques et marno-calcaires et épisodes gréseux
n5-6 Schistes épimétamorphiques, quartzites
n6 Flych bleu sombre à épisodes gréseux
n6a Flych bleu sombre à épisodes gréseux et schistes bleus
r-t Petites pourpres à violacées parfois satinées
p2-3 Permien supérieur _ pélites pourpres
p1 Permien inférieur _ Conglomérats et grés
t2 Trias moyen _ argiles roses, gypse
t Dolomies grises, litées
t1 Trias inferieur _ Grés blancs
tr1 Trias superieur-Rhétien _ Marnes et dolomies plus ou moins sombres
td Trias _ dolomies claires et sombres
BV. Feddal
BV. Snada
BV. Boussekour
BV. Béni Boufrah
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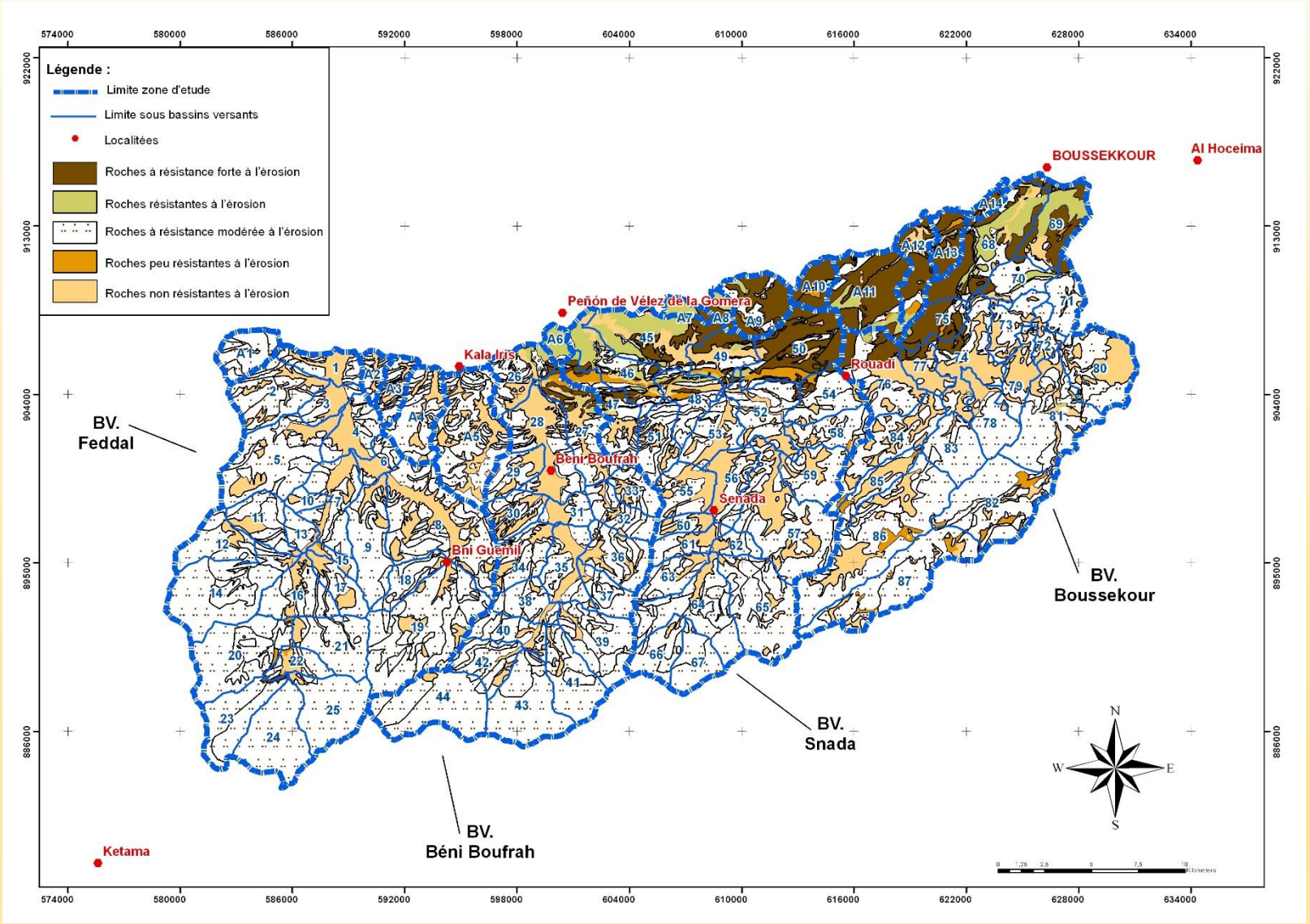
Lithology


Légende :
Limite zone d'etude
Limite sous bassins versants
Localitées
Roches à résistance forte à l'érosion
Roches résistantes à l'érosion
Roches à résistance modérée à l'érosion
Roches peu résistantes à l'érosion
Roches non résistantes à l'érosion
BOUSSEKKOUR
Al Hoceima
Peñón de Vélez de la Gomera
Kala Iris
Rouadi
Beni Boufrah
Senada
Bni Guemil
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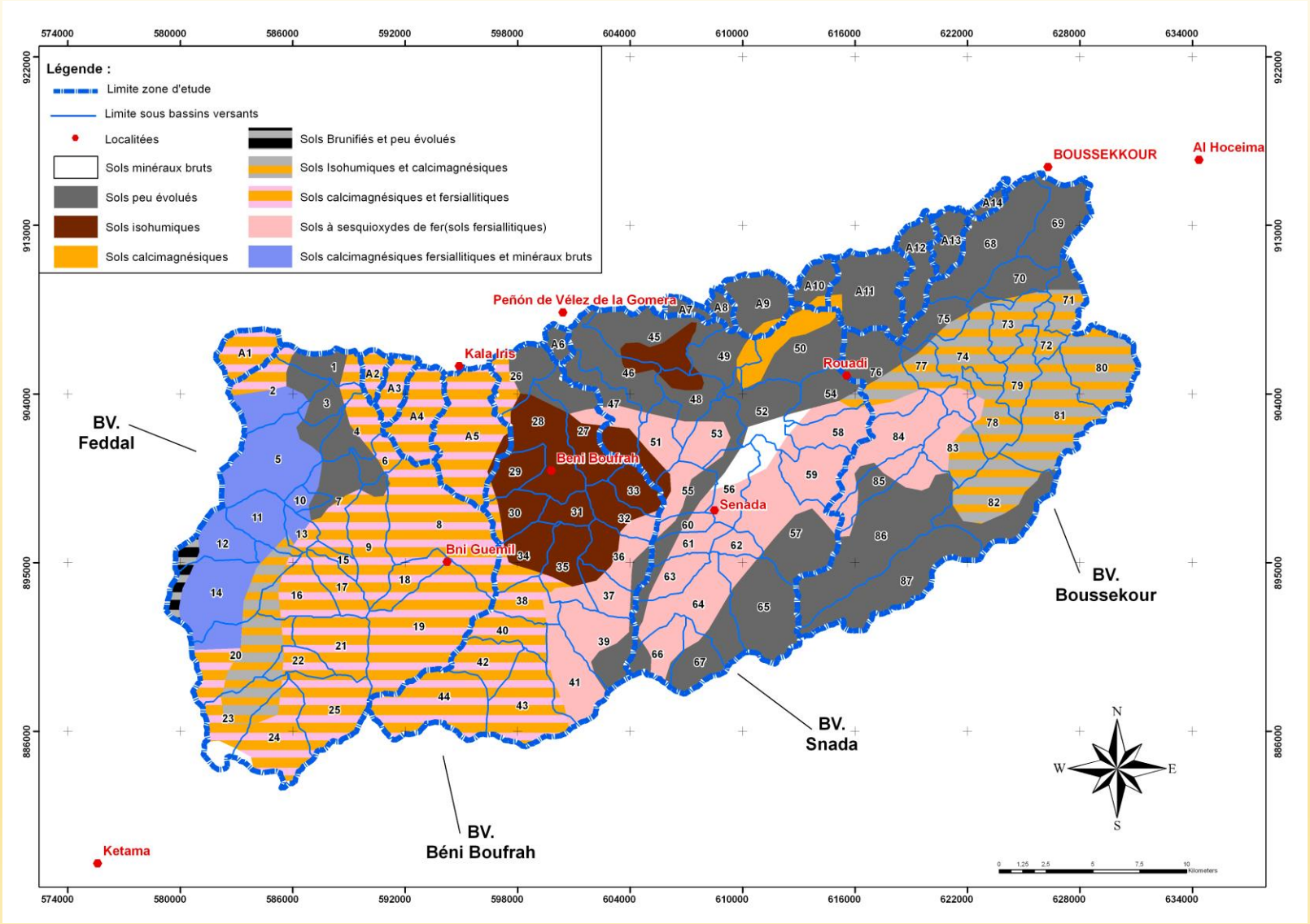
Pedology


Légende :
Limite zone d'etude
Limite sous bassins versants
Localitées
Sols minéraux bruts
Sols peu évolués
Sols isohumiques
Sols calcimagnésiques
Sols Brunifiés et peu évolués
Sols Isohumiques et calcimagnésiques
Sols calcimagnésiques et fersiallitiques
Sols à sesquioxydes de fer(sols fersiallitiques)
Sols calcimagnésiques fersiallitiques et minéraux bruts
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Al Hoceima
Peñón de Vélez de la Gomera
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Beni Boufrah
Senada
Bni Guemil
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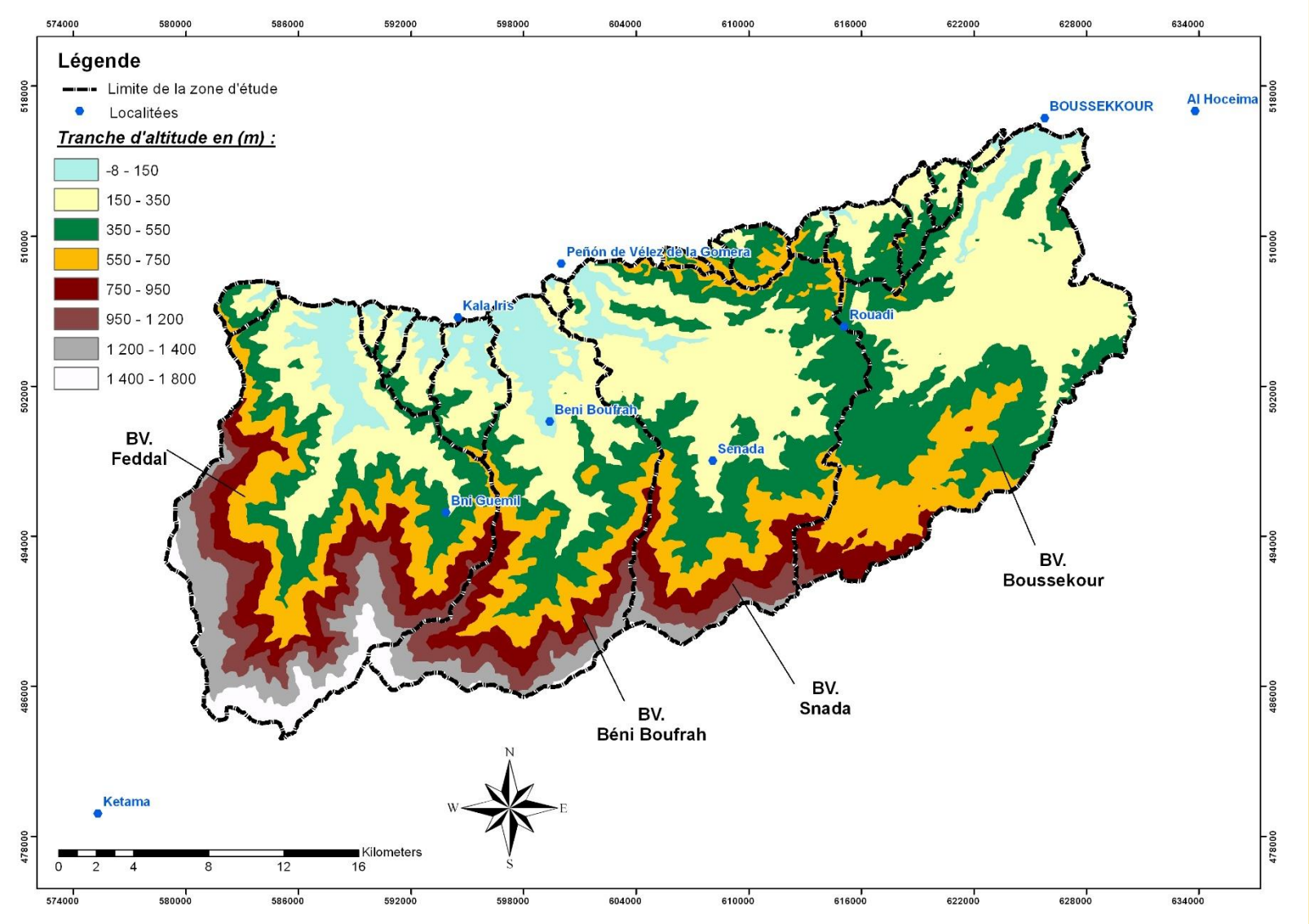
Kilometers

Relief


Légende
Limite de la zone d'étude
Localitées
Tranche d'altitude en (m) :
-8 - 150
150 - 350
350 - 550
550 - 750
750 - 950
950 - 1 200
1 200 - 1 400
1 400 - 1 800
BOUSSEKKOUR
Al Hoceima
Peñón de Vélez de la Gomera
Kala Iris
Rouadi
Beni Boufrah
Senada
Bni Guemil
Ketama
BV. Feddal
BV. Boussekour
BV. Béni Boufrah
BV. Snada
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Kilometers
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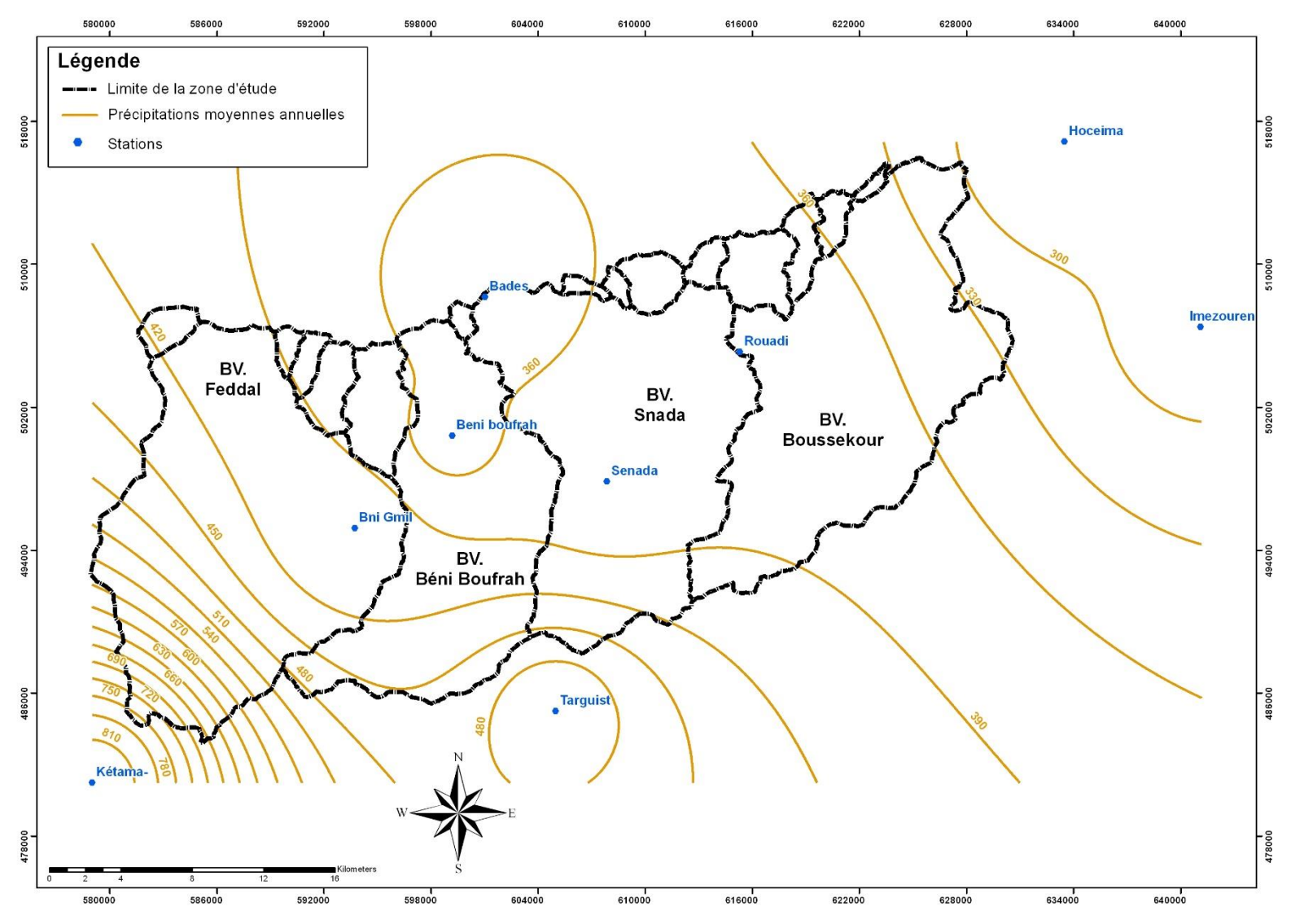
518000 510000 502000 494000 486000 478000

Climate


Légende
Limite de la zone d'étude
Précipitations moyennes annuelles
Stations
Hoceima
Imezouren
Bades
Rouadi
Beni boufrah
Senada
Bni Gmil
Targuist
Kétama-
BV. Feddal
BV. Snada
BV. Boussekour
BV. Béni Boufrah
420
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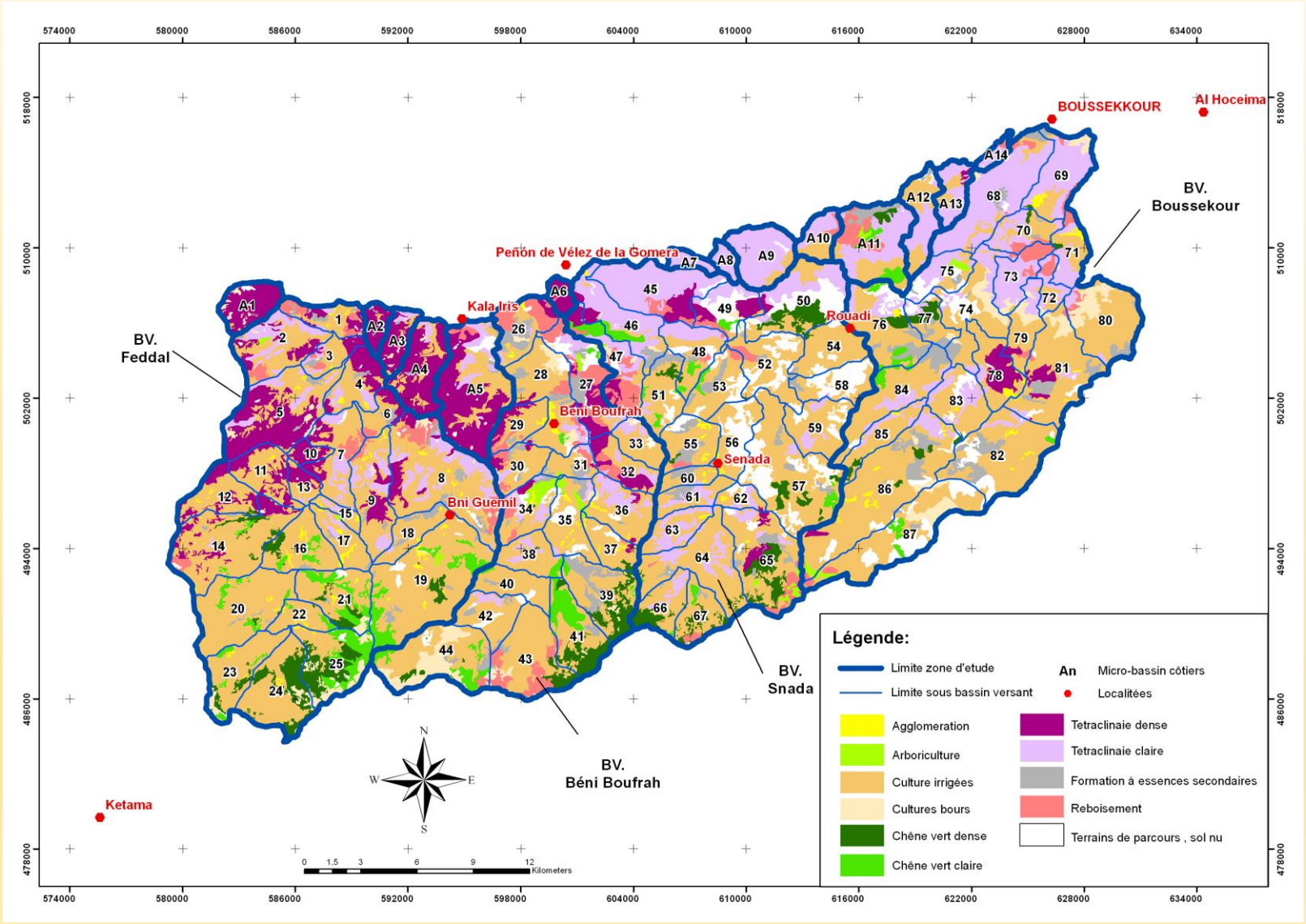
Land cover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Kala Iris
Rouadi
Béni Boufrah
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BV. Boussekour
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BV. Béni Boufrah
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A14
Légende:
Limite zone d'etude
Limite sous bassin versant
An
Micro-bassin côtiers
Localitées
Agglomeration
Arboriculture
Culture irrigées
Cultures bours
Chêne vert dense
Chêne vert claire
Tetraclinaie dense
Tetraclinaie claire
Formation à essences secondaires
Reboisement
Terrains de parcours , sol nu
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Kilometers

PRESENTATION OF THE APPROACH METHODOLOGY

Adopted methodology

Mapping and measurement of erosion using PAP/RAC method

It will allow us to :

- understand the problems of the large basin in terms of erosion risk, land use and the interaction of biophysical and anthropogenic factors.
- identify, describe and measure the dynamic processes of water erosion, such as irreversible degradation on the one hand, and stable unaffected areas on the other.
- It contributes to the qualitative characterization of soil losses.

Adopted methodology

PAP/CAR method

- based on natural factors :

(Lithology, slope, vegetation cover and cover density)

- Technically based on 3 approaches :

  - **The predictive approach**
  - **The descriptive approach**
  - **The integration approach**

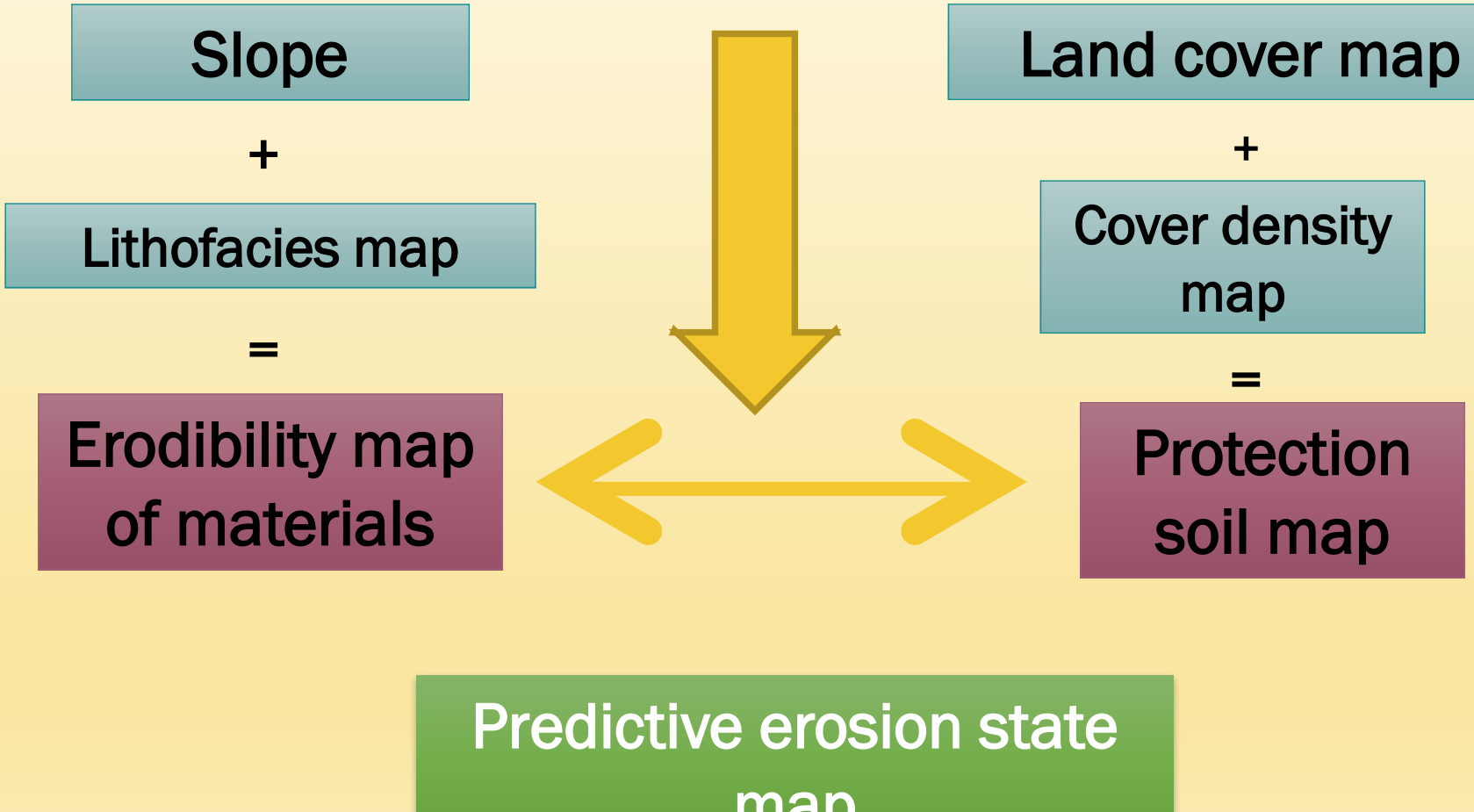
PAP/CAR method

- **The predictive approach:**

It consists of identifying, evaluating and integrating all the fundamental parameters to determine preliminary assumptions, as well as obtaining information on the current state of land degradation based on the degree of influence of different factors that control erosion (lithology, slope, land use, soil protection…).

It results in the mapping of homogeneous units of erosive states, providing the framework for mapping potential and general trends.

Predective approach



PAP/CAR method

- Desctiptive approach:

It consists of describing and qualitatively evaluating the current and active processes at a given site, as well as identifying, evaluating and mapping the current erosion processes and the different degrees achieved by each form of erosion.

Descriptive approach

Predictive approach

Mapping the erosion forms

Erosion forms map

+

Predictive erosion state map

Consolidated map of water erosion

PAP/CAR method

- Integration approach:

This is the main result, which is the **final map of water erosion trends** towards degradation or regression.

It is obtained by superimposing and integrating qualitative information from the predictive and descriptive phases.

STUDY OF THE POTENTIAL SOIL DEGRADATION IN BENI BOUFRAH WATERSHED

1- ERODIBILITY MAP OF BENI BOUFRAH WATERSHED

I. a- Development of the Slope Map

According to PAP/CAR, the slopes are divided into 5 main classes:

PAP/CAR code	Slope classes
1	Null to low (0-3%)
2	Moderate (3-12%)
3	Abrupt (12-20%)
4	Very abrupt (20-35%)
5	Extreme (>35%)

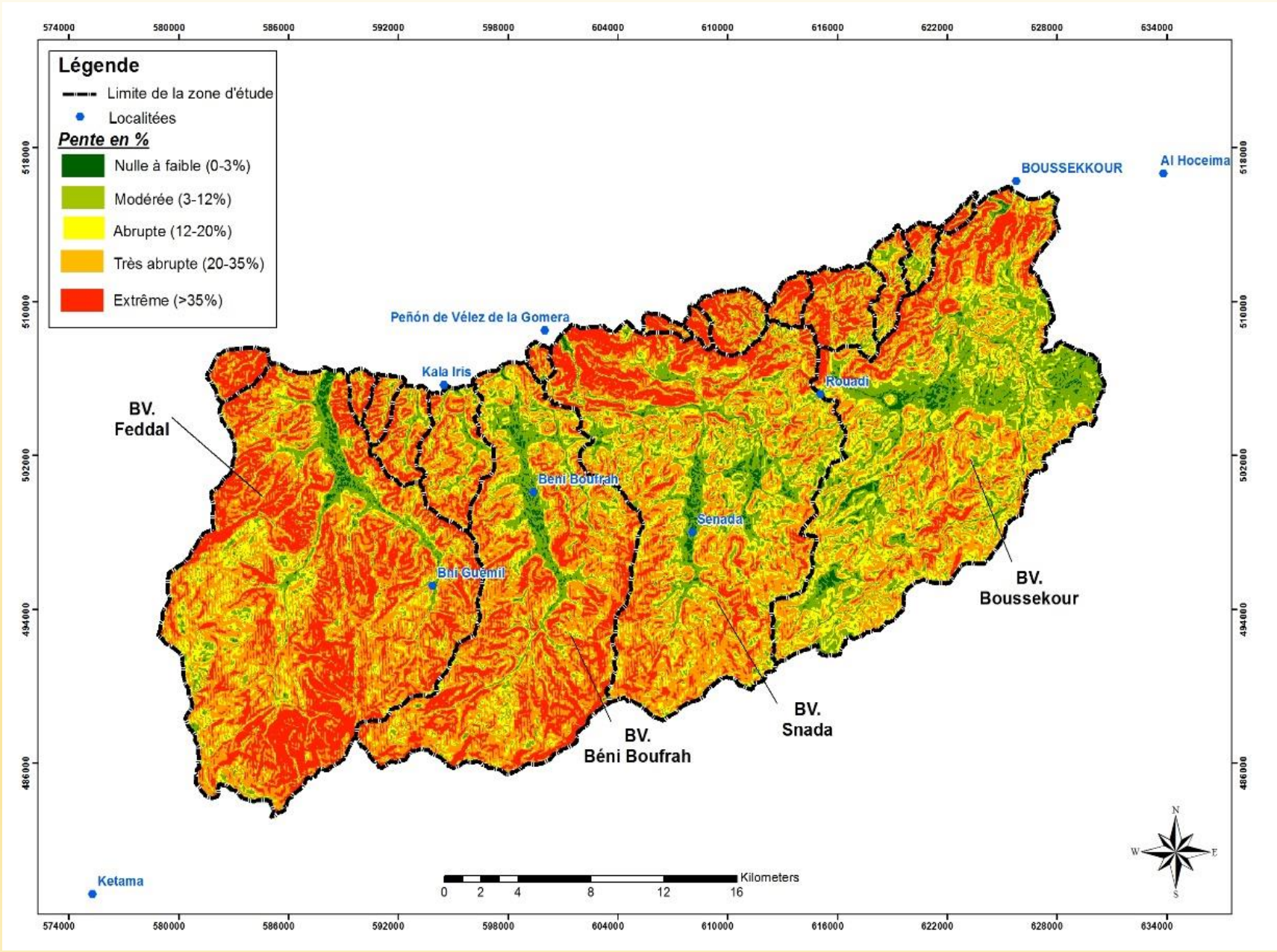
The process:

the delineation of all identifiable troughs based on the reference topographic map or contour lines of the topographic map,

the realization of a digital terrain model (DTM),

the elaboration of the slope map from the DTM produced.

Slope map


Légende
Limite de la zone d'étude
Localitées
Pente en %
Nulle à faible (0-3%)
Modérée (3-12%)
Abrupte (12-20%)
Très abrupte (20-35%)
Extrême (>35%)
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BV. Snada
BV. Béni Boufrah
Kilometers
0 2 4 8 12 16
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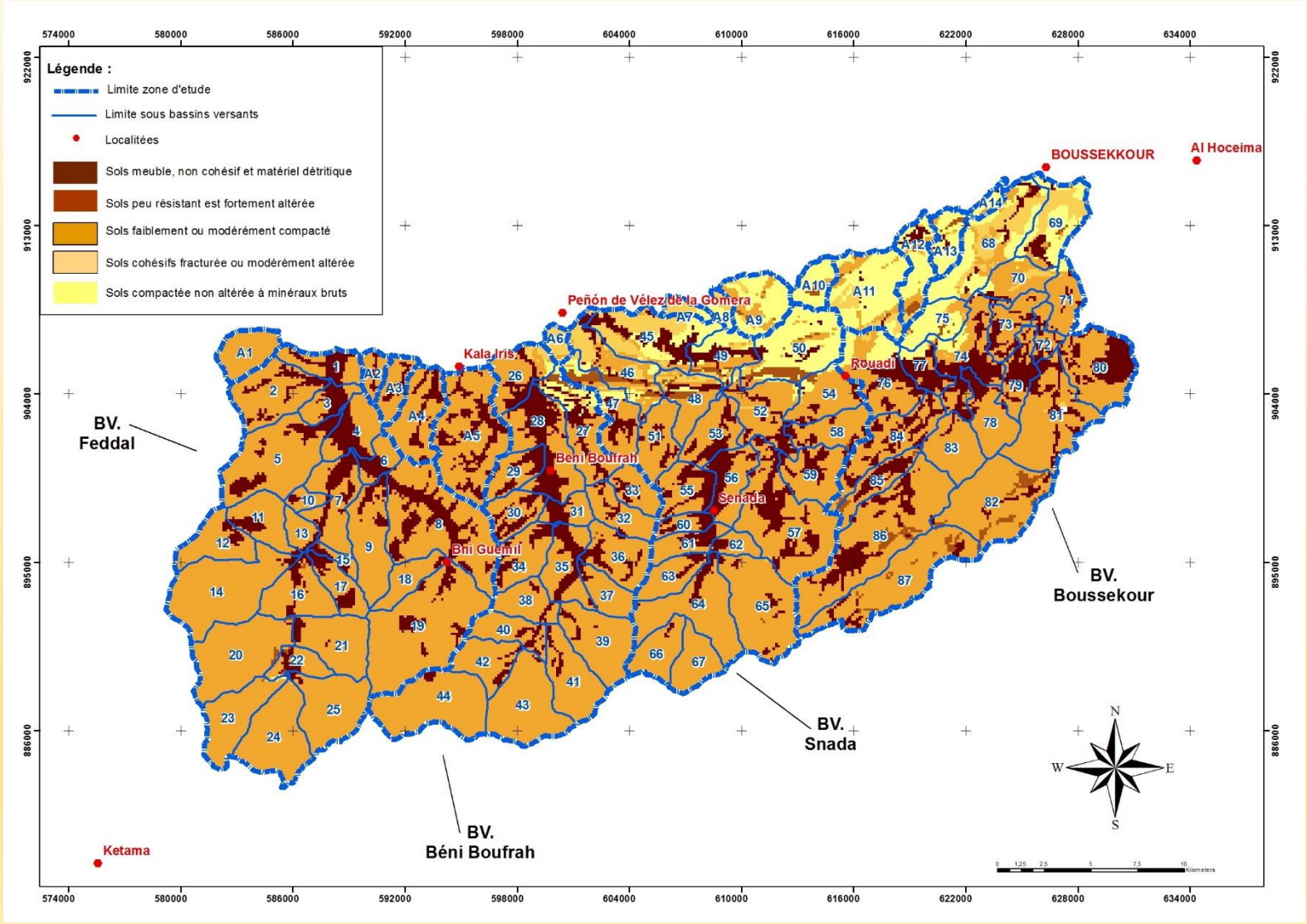
I.b- Development of the lithofacies map

Lithofacies class	Degree of soil cohesion
1	Unaltered compacted soils with raw minerals
2	Cohesive soils fractured or moderately altered
3	Slight to moderately compacted soils
4	Poorly resistant soils are strongly altered
5	Soft, non-cohesive soils and detrital material

- The litho-facies map is based on geological, lithological or soil data.
- In our case, we based ourselves on soil data: the latter identify the different types of soil on the surface and classified according to the relative degree of cohesion and mechanical and physical resistance to erosion.
- The different soil outcrops are divided into 5 classes, and a code is assigned to each degree of friability.

Lithofacies map



I.C- Development of the Soil Erodibility Map

Slope classes	Litho-facies classes				
	1	2	3	4	5
1	1	1	1	1	2
2	1	1	2	3	3
3	2	2	3	4	4
4	3	3	4	5	5
5	4	4	5	5	5

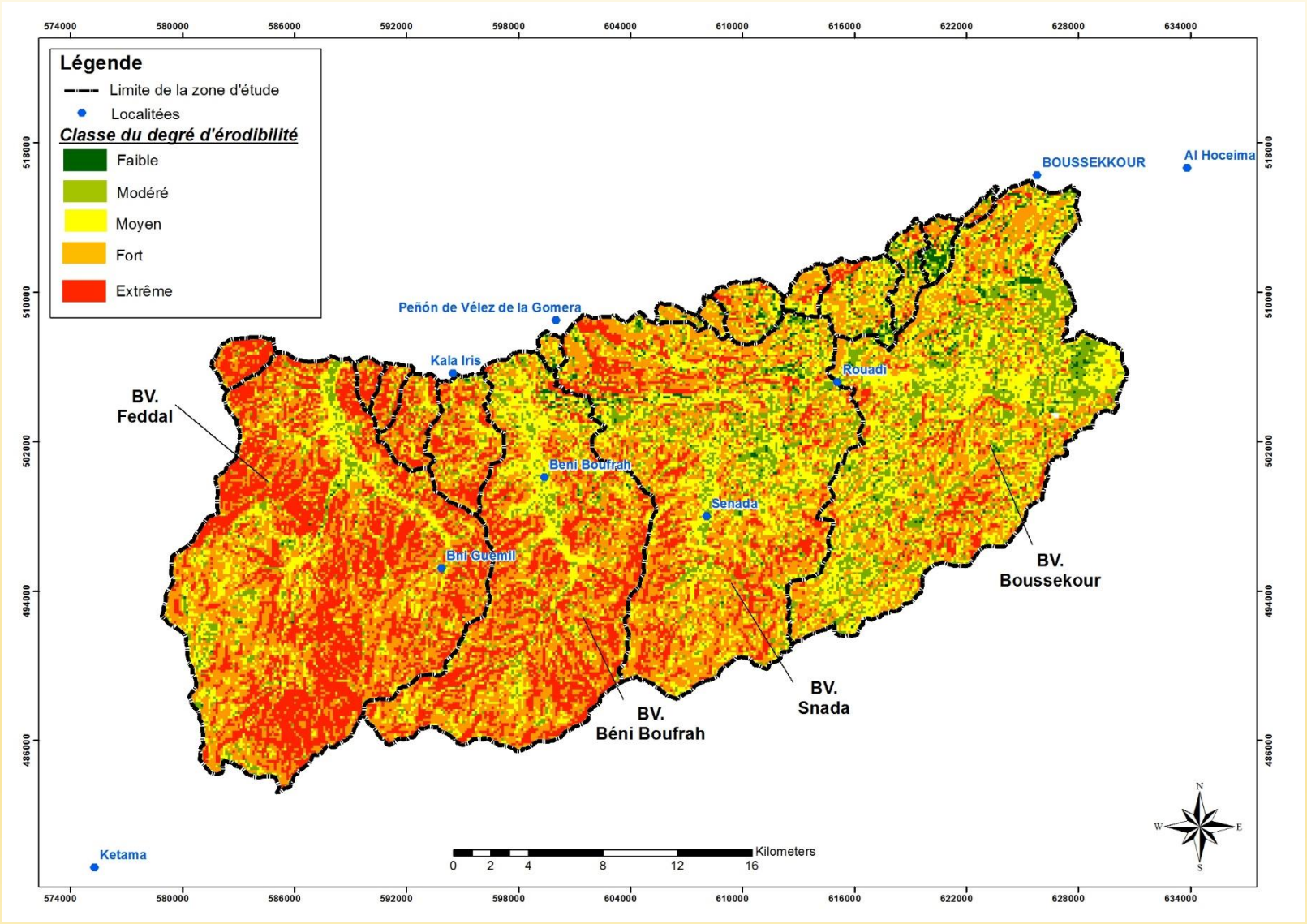
Soil erodibility matrix

Class	Erodibility degree
1	Low
2	Moderate
3	Medium
4	High
5	Extreme

Degree of friability

- This is the result of the superposition of the slope map and the soil map.
- The polygons resulting from the superposition of the two reference maps are classified according to the soil erodibility matrix.

Erodibility map



2- DEVELOPMENT OF THE SOIL PROTECTION MAP

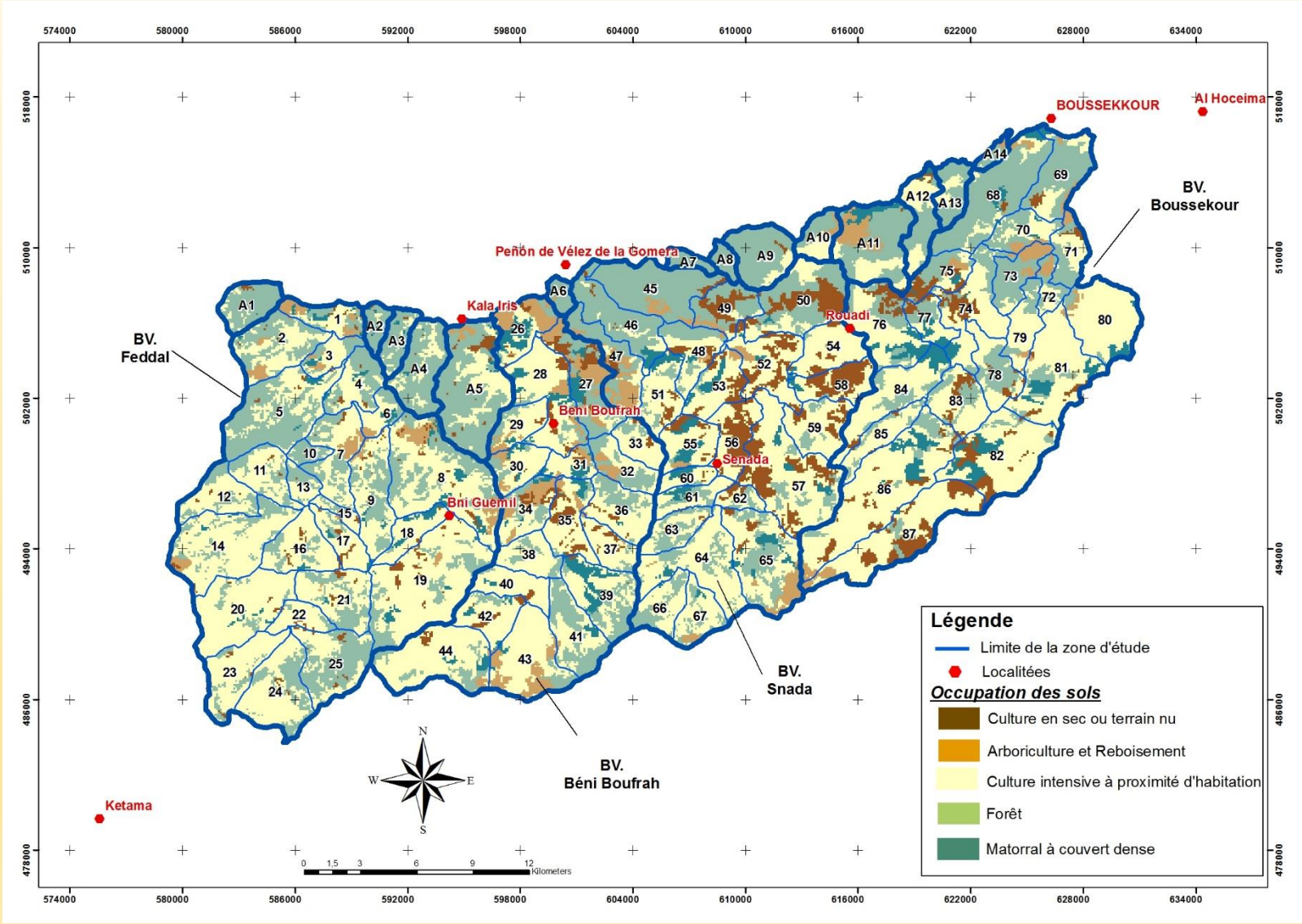
I- Preparation of the Land Use Map

Classes	Land cover
1	Culture in dry or bare ground
2	Arboriculture and reforestation
3	Intensive cultivation near housing
4	Natural forests
5	Dense Covered Matorrals

Land cover map classes

- It is identified by means of supervised classification under ArcGIS Pro, then transferred to the sub-basin map.

Land use map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Kilometers
Légende
Limite de la zone d'étude
Localitées
Occupation des sols
Culture en sec ou terrain nu
Arboriculture et Reboisement
Culture intensive à proximité d'habitation
Forêt
Matorral à couvert dense

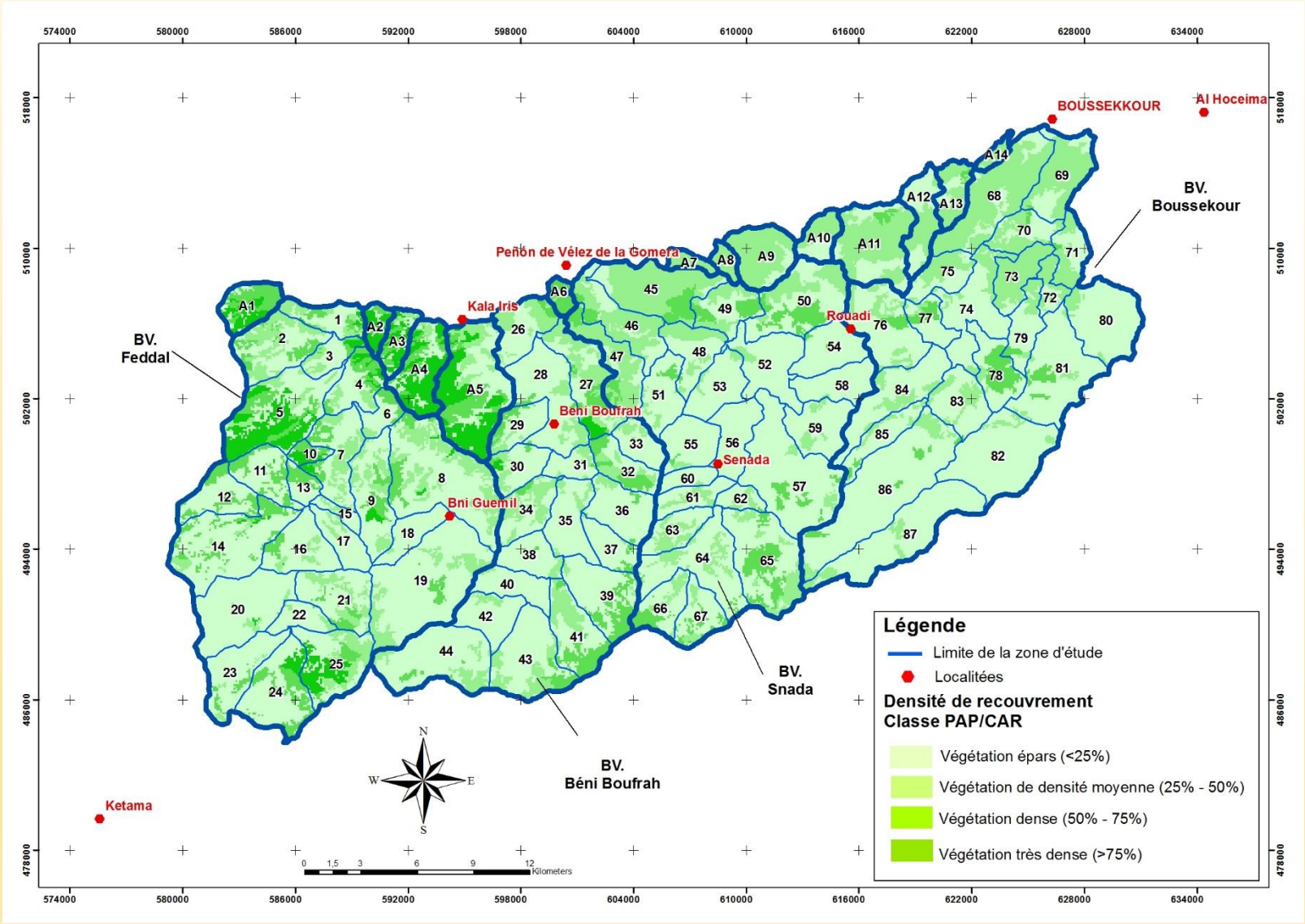
II- Development of the coverage density map

- The production of this map incorporates a classification based on direct observation of land use categories.

- A map of the degree of vegetation cover and thus prepared. 4 classes are identified:

Classes	Degree of vegetation coverage
1	Scattered vegetation (<25%)
2	Medium density vegetation (25%-50%)
3	Dense vegetation (50%-75%)
4	Very dense vegetation (>75%)

Degree of vegetation cover map



Soil protection map

- The soil protection map represents the result of superimposing the land use map and the density map of the vegetation cover, depending on the type and degree of distribution of the vegetation.
- The objective of this map is to prioritize the surface of the Beni Boufrah watershed according to the degree of protection that the vegetation cover can provide.
- This step is necessary to identify the role of vegetation cover.

Land use	Degree of vegetation coverage			
	1	2	3	4
1	5	5	4	4
2	5	5	4	3
3	3	2	1	1
4	4	3	2	1
5	5	4	3	2
6	5	4	3	2

Soil protection matrix

PAP/CAR classes	Soils protection degree
1	Very high
2	High
3	Medium
4	Low
5	Very low

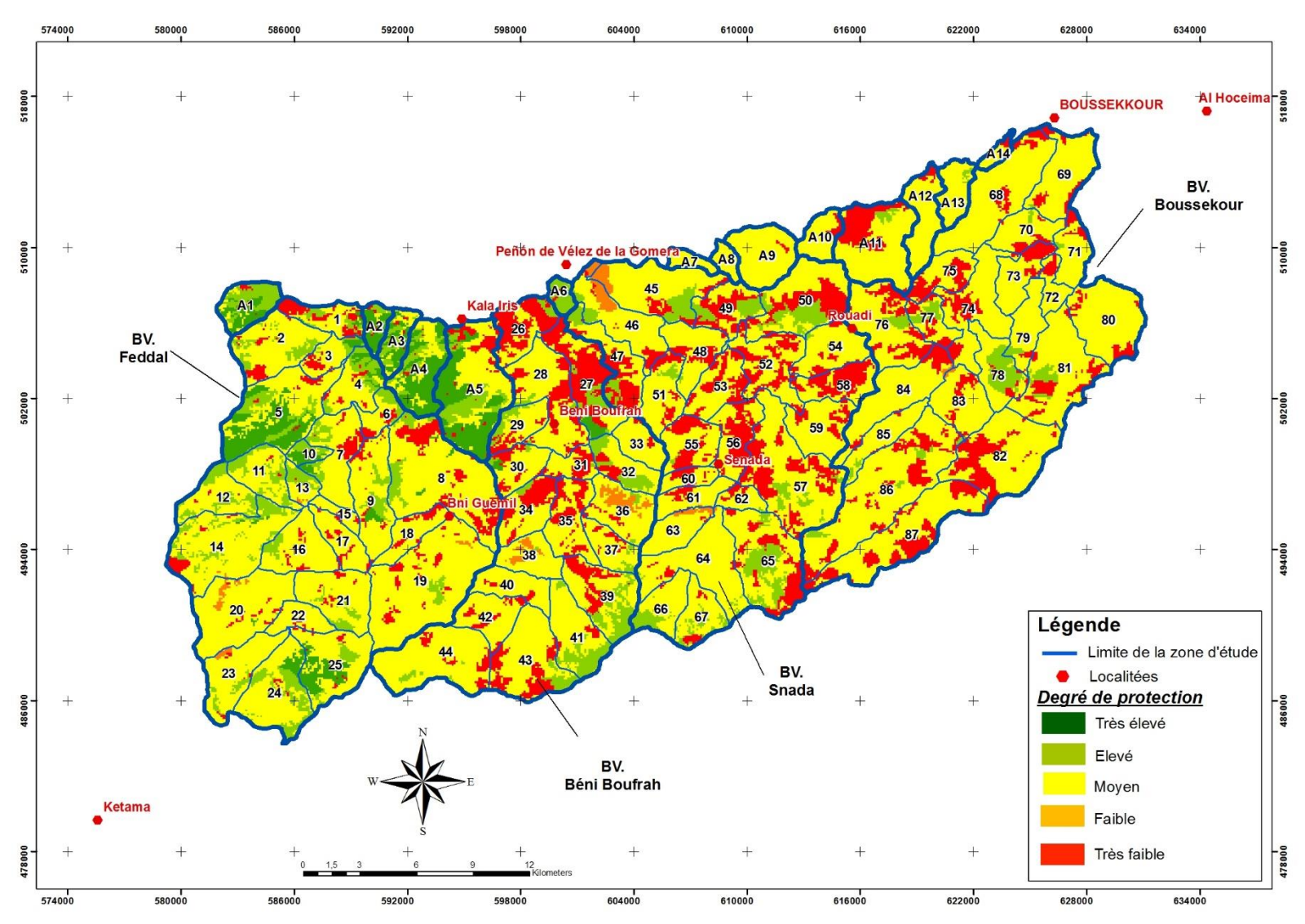
Soils protection classes

III- Elaboration of the Protection map

- The superposition of the two maps is done by applying the representative matrix in the table (soil protection matrix), which allows to erase the boundaries separating the polygons with the same degree of soil protection.

Soil protection is defined as the resistance that the nature of the vegetation cover offers to the substrate, it depends on the land use and their degree of protection.

Soil protection map



3- DEVELOPMENT OF THE MAP OF EROSIVE STATES

Degree of soil protection	Degree of erodibility				
	1	2	3	4	5
1	1	1	1	2	2
2	1	1	2	3	4
3	1	2	3	4	4
4	2	3	3	5	5
5	2	3	4	5	5

Matrix of soil erosion states

Elaboration of the map of erosive states

- The map of erosive states is the final product of the predictive phase, resulting from the superposition of the erodibility map and the soil protection degree map.
- The superposition is done by applying the matrix presented in the table.

Elaboration of the map of erosive states

The purpose of this map is to:

highlight the different combinations of the degrees of influence of the factors that control water erosion: slope, soil type, cover density, type of occupation.

to prioritize the surface of the Beni Boufrah watershed, in units according to the degree of erosion.

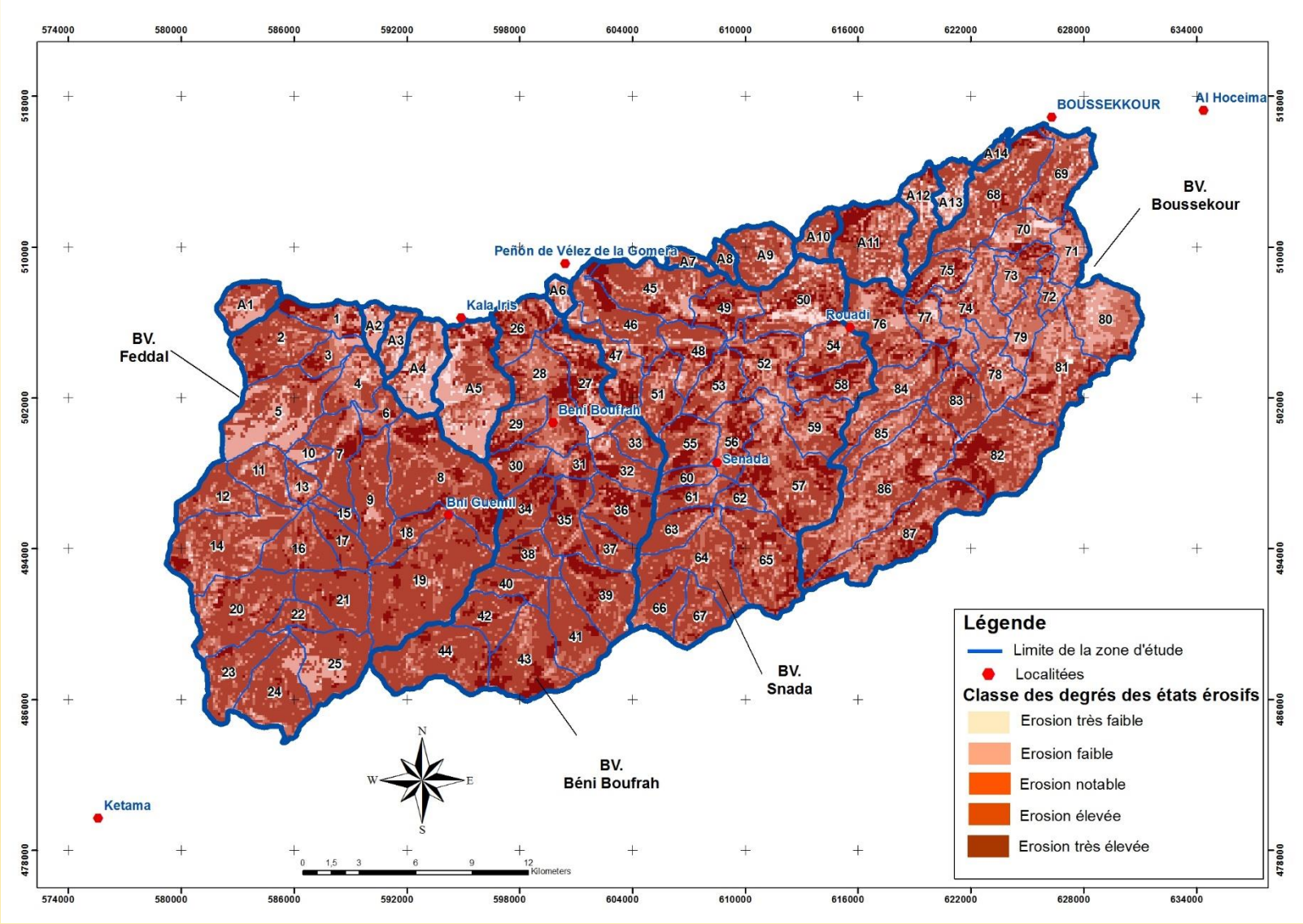
Elaboration of the map of erosive states

Classes	Erosive states degree
1	Very low
2	Low
3	Notable
4	High
5	Very high

Class of degrees of erosive states

- The coding legend is indicated by the map of erosive states, according to the table

Erosive states map



Analysis of the map of erosive states

Considering the factors of erosion that prevail, the watershed of the Beni Boufrah is very vulnerable to erosion, this is due in fact to the fact that all the factors act by their highest degrees, whether for erodibility or for soil protection.

4- DEVELOPMENT OF THE MAP OF DESCRIPTIVE EROSIVE STATES

Descriptive approach

The descriptive approach is based on the cartographic delimitation of erosion forms and erosive processes

Development of the map of descriptive erosive states

PAP/CAR indicators	Erosion form of Beni Boufrah watershed
L1	Low erosion, restricted vegetation cover, sheet erosion
L2	Low erosion, intense sheet erosion
L3	Slow erosion, cutting, diffuse scratching, sheet erosion
D1	Slow erosion, gullies, surface gullies on the slope
C1	Severe erosion, medium deep gully
MX	Important erosion, Solifluxion
CX	Severe erosion, Badlands area

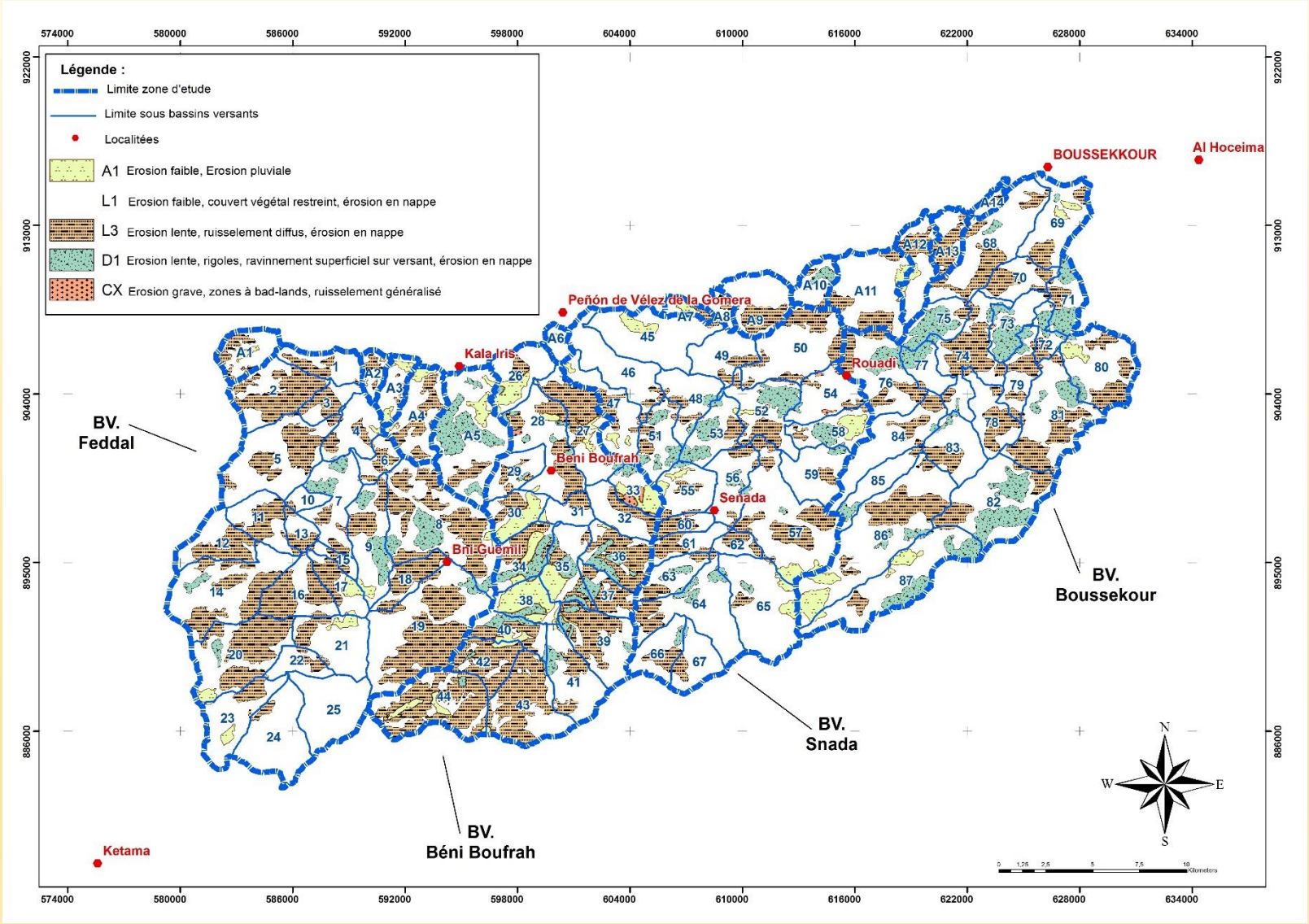
Codification of the forms of erosion encountered in the Beni Boufrah watershed

- Consists of designating the intensity of the erosive process.
- This is mainly a qualitative evaluation that should be considered as complementary to the predictive phase.

Mapping of erosion forms

- The map of erosion patterns is based on field observations, as well as the use of Sentinel data

Erosion forms map



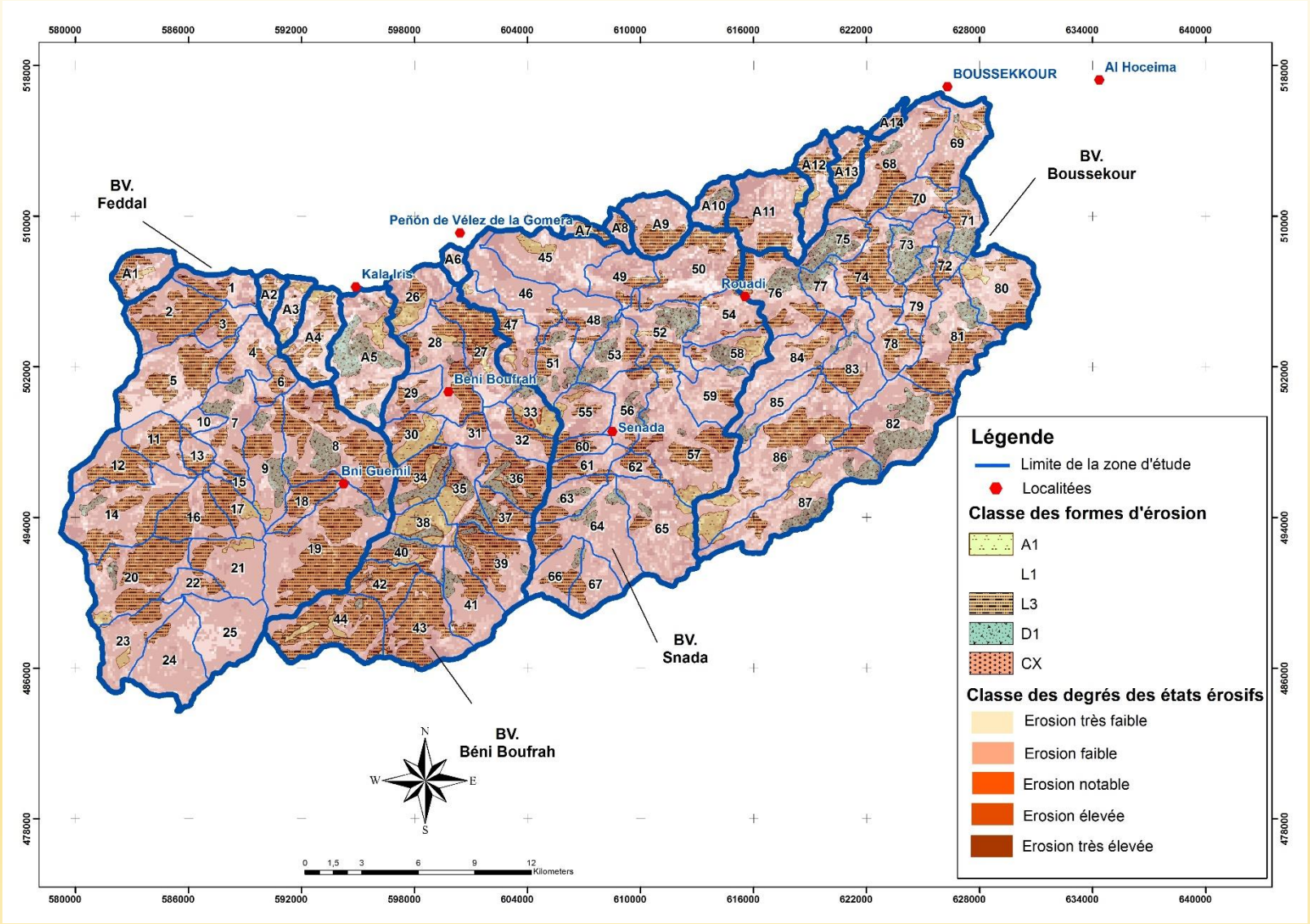
5- ELABORATION DE LA CARTE CONSOLIDÉ DE L'ÉROSION

Integration approach

Consolidated erosion map:

- The final map is a qualitative map, combining descriptive and predictive data, and containing complete information on the different aspects of erosion phenomena.
- The description of the forms of active erosion and the more specific erosion risks (environment identifiable through their main causal factors), are complementary to the data provided by predictive mapping, which implies the final diagnosis of erosion must be expressed by a symbol.

Consolidated map of water erosion

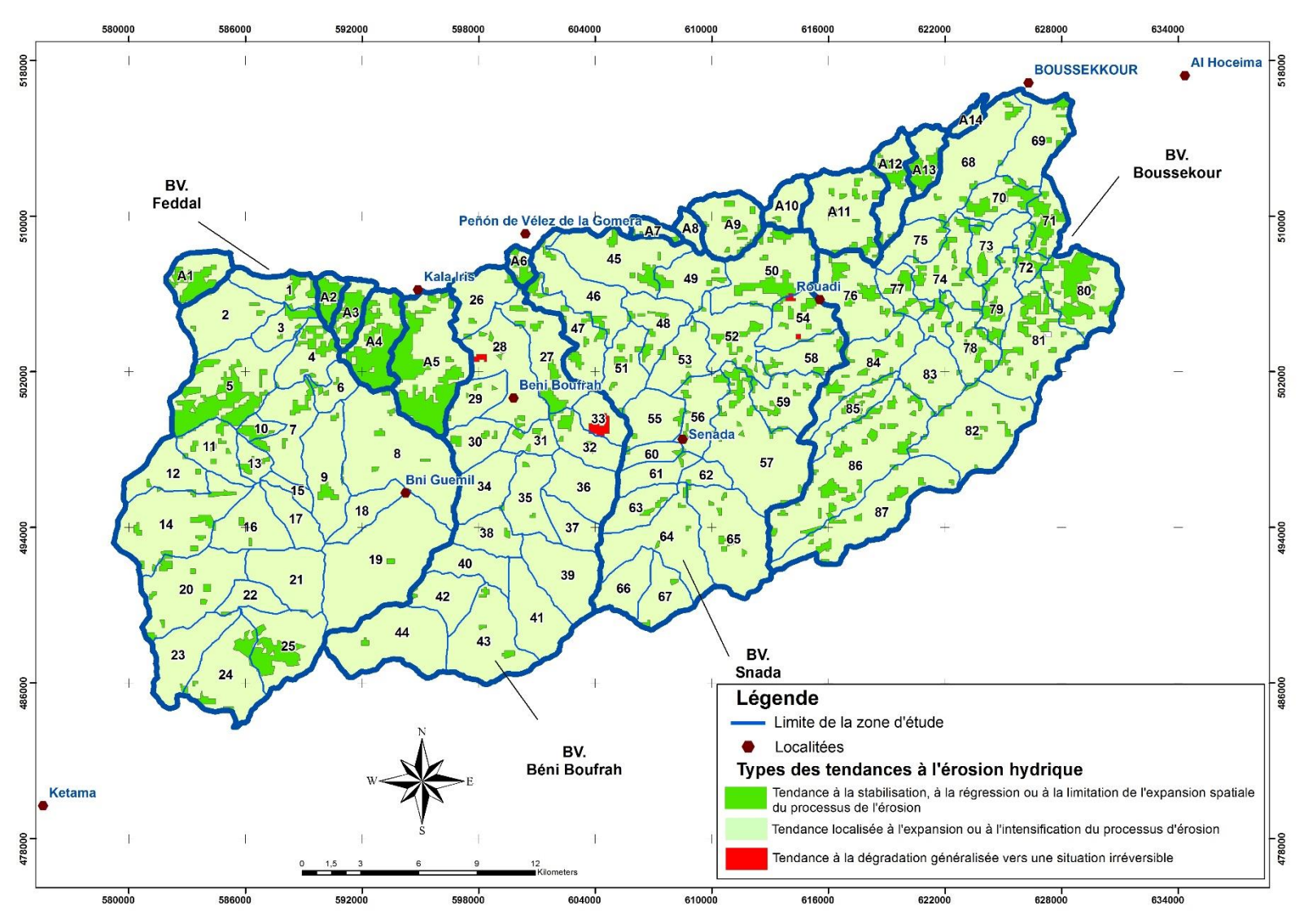


Water Erosion Trends Map

- The final product of the integration phase is the final map of erosion trends obtained by combining all predictive and descriptive data.

- Trends are assessed by superimposing the table of erosive states and the table of forms of erosion.

Map of water erosion trends



Conclusion

- Almost all the land at the Beni Boufrah watershed area has suffered remarkable disturbances.

- The mapping and estimation of water erosion using the consolidated PAP/RAC method based on natural factors (slope, vegetation cover, lithology, occupation) made it possible to prioritize the Beni Boufrah watershed in plots according to the degree of erosion risk.

Conclusion

- *The map of the predictive approach*

Provides information on the current state of land degradation

- *The descriptive approach*

has shown that this degradation is manifested by different processes of water erosion

Conclusion

- The superposition of predictive and descriptive mapping has therefore made it possible to show the global trends in the surface evolution of the soils of the catchment area,

- It also shows trends in regression/decline trends.

Recommandations

- In view of the threats of degradation to the natural resources and infrastructure of the catchment area and consequently to the quality of life of the inhabitants from an economic and social point of view, it is necessary to take action to combat erosion using a global and innovative approach that will make it possible to reconcile the important needs of a population that is constantly growing and the limited potential of natural resources that are becoming poorer as a result of their overexploitation combined with misuse.

THANK YOU