SHORT COMMUNICATION

Mapping of physiognomic changes in steppe vegetation using geomatic tool: case of the Naâma region (South West Algeria)

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ABSTRACT

For several decades, the steppe region has been undergoing advanced degradation due to the combined effects of climatic and anthropogenic factors. This study was conducted to monitor the dynamics of the different steppe plant formations and to demonstrate the value of geomatics for spatial management and decision-making. Mapping and processing of Landsat-8 satellite images from 2018 made it possible to map and assess this evolution between 1978 and 2018. The results show a decline in the area occupied by the paraclimax steppe from 391240 ha (83.51%) in 1978 to 304056 ha (65%) in 2018. The psammophilous steppes also experienced a very significant increase, from 26410 ha in 1978 to 128838 ha in 2018. The regressive dynamics of the vegetation cover is accompanied by significant dune movements and a considerable reduction in the area of the matorrals of Juniperus phoenicea L and Stipa tenacissima L.

Keywords: Anthropogenic factors, dynamics, Landsat-8 satellite, matorrals, psammophilous steppes, steppe region,

The rapid loss of biodiversity is one of the most critical environmental challenges faced by the present generation (Ekanayake and Fernando, 2021). Climatic factors and human action are the main factors responsible for the decline in biodiversity (Mamadzhanov *et al*., 2024). The high plains of southern Oran are very fragile steppe rangelands where the ecological and socio-economic balance is compromised by the combined effects of severe climacic hazards dominated by drought and increasing anthropogenic pressure on natural resources. The steppe ecosystem is in a state of permanent deterioration so that urgent measures are needed to protect, conserve, regenerate, improve and manage the natural area (Khader *et al*., 2009, Amara *et al*., 2025).

Steppe spaces of the Naâma area are rather well representative of all steppe spaces of western Algeria. They are exploited as rangelands with a mean carrying capacity of 10 sheep/ ha although the possibilities are only of 0.9 ha / sheep (Mekhloufi *et al*., 2020). The regressive evolution of vegetation, characterized by the gradual replacement of para-climacic steppes with *Stipa tenacissima* L., *Artemisia herba-alba* Asso and *Lygeum spartum* L by degraded steppes with low productivity, dominated by thorny and toxic species such as *Atractylis* *serratuloides* Sieber ex Cass., *Peganum harmala* L and *Noaea mucronata* (Forssk.) Asch. & Schweinf. The gradual evolution of the psammophilous formations is related to the dune movements that shape their environment.

In addition, diachronic analysis by remote sensing makes it possible to understand the evolution of the environment and the processes of regression or progression of vegetation over periods of up to tens of years. The objective of our research is to show how the comparison of satellite images between two different periods (1978 and 2018) makes it possible to assess the extent of the physiognomic changes that have occurred in the vegetation cover in the Naâma and Mecheria region and to locate the area's most affected and most threatened by the silting process and therefore the areas where priority action should be taken.

The choice of the period for studying physiognomic changes was not random. It was practically between 1970 and 2018 that the Algerian steppe experienced major changes in its vegetation cover following the accentuation of the phenomenon of desertification and overgrazing. After 2018 and until today, the situation of the steppe has not changed.

The study area is part of a pastoral region covering an area of 29514 km² (Hadjadj and Guerine, 2024). It is located between the Tellian and Saharian atlas in its western part, bordered to the north by the wilayates (provinces) of Tlemcen and Sidi bel Abbés, to the south by the wilaya of Bechar, to the east by the wilaya of El-Bayadh and to the west by the Kingdom of Morocco. The surface area of grazing land is 2 153740 ha, including 430000 ha of esparto grass cover and 514300 ha of forests and scrubland (Benguerai, 2011). The study area extends over two communes Mécheria and Naâma, covering an area of 486500 ha at altitudes ranging from 1128 to 2100 m.

Steppe soils are calcareous, characterised by a shallow depth, a very low organic matter content (less than 1%) which decreases with depth, while the level of limestone increases and hinders plant development. The texture is predominantly sandy, with poor structural stability and low water retention capacity, allowing only xeric vegetation adapted to these environmental conditions to develop (Benabdeli, 2000). In general, the study region is characterized by an average annual rainfall of less than 190 mm/year (period 1990-2022). This precipitation is irregular, low, and stormy. The average annual temperature is 19.5°C. The hottest month is July with a temperature of 30.5°C and the coldest is January with a temperature of 7.5°C. The Emberger pluviothermal quotient calculated for this period is 20.3, which allows the study area to be classified in the lower arid bioclimatic zone with cool winters. The dry season in the region extends almost throughout the year (Hadjadj and Guerine, 2024; Amara *et al*., 2025). The sirocco blows for an average of 36 days a year, concentrated in June and July (Louassa, 2010).

The perennial plant formations of the area are dominated by degradation facies of steppes with *Stipa tenacissima* L, *Lygeum spartum* L which constitute poor rangelands and relicts of chamaephytic steppes based on *Artemisia herba-alba* Asso as well as degradation facies based on *Noaea mucronata* (Forssk.) Asch. & Schweinf. and *Thymelea microphylla* Coss. The study area is marked by the presence of wooded steppes with *Pistacia atlantica* Desf. associated with formations of *Ziziphus lotus* (L.) Lam. The mountain area is characterized by the presence of pre-forest formations, these are sparse shrub formations of *Quercus ilex* subsp. *Ballota* (Desf.), *Pinus halepensis* Mill (artificial formations), *Juniperus phoenicea* L and *Juniperus oxycedrus* L (Hadjadj *et al*., 2020).

The municipality of Mecheria has approximately 109991 inhabitants in 2002 according to the planning and budget monitoring department, which represents almost 1/3 of the total population of the wilaya of Naâma. For the commune of Naâma, the population is estimated at around

28753 inhabitants in 2021, which represents nearly 9% of the total population of the wilaya of Naâma (Amara *et al*., 2025).

The proportion of the nomadic population in the two communes has decreased significantly, it is less than 5% (2.60% in Mecheria and 1.74% in Naâma) of the total population of the two communes. This decrease is due to the reduction of transhumance and sedentarization caused by rural housing programs, leading to overexploitation of the rangelands. Agro-pastoral activity remains a determining factor, pastoralism is the traditional productive activity of the steppe (Hadeid, 2008). The total agricultural area of the wilaya is 2203460 ha, of which the useful agricultural area represents only 1.14%, or 25019 ha, and the rest (2178441 ha) is made up of pastures. The pastoral livestock in this steppe area is estimated at around 1273094 heads, of which the predominant species is sheep (around 91.25% of the livestock) (Amara *et al*., 2025).

The method used to assess the dynamics of plant formations is based on the 1978 phytoecological map, vegetation surveys, a 2018 Landsat-8 satellite image and Geographic Information Systems. The approach consists of digitising the 1978 phytoecological map, supervised classification of the satellite image, field survey and finally a comparison between the two maps of plant groupings. The investigation area on the satellite image was delimited by entering the coordinates of the four corners of the map, so that the remaining part of the image corresponds exactly to the map.

There are three main stages in processing the satellite image: pre-processing, classification of the image using the Maximum Likelihood algorithm and production of the 2018 plant ecology map. Geometric correction of the satellite image and the 1978 plant ecology map in the same geographical reference frame (UTM, Zone 31 North).

In order to make the 1978 phytoecological map comparable to the one produced in 2018, the biotope parameters of the plant groups had to be taken into account based on the ranges of the main species characteristic of the environment, the field surveys of Gaddas (Gaddas, 2001) and the work carried out by (Khader *et al*., 2022) made this comparison possible. Vegetation dynamics were assessed by mapping the location of physiognomic vegetation units potentially containing the habitats of the various dominant species (para-climatic degradation, sandy areas, closed depressions, relief). Assessing the accuracy of the classification is very important for understanding the results obtained and using them for decision-making (Plourde and Congalton, 2003). The most common elements of accuracy assessment are overall accuracy, producer accuracy, user accuracy and the Kappa coefficient (κ). The scientific literature has provided meanings and calculation methods for these elements (Plourde and Congalton, 2003; Foody *et al*., 2003).

In our case, the supervised classification performed, the overall accuracy and the Kappa coefficient were calculated to give an idea of the quality of the classification. One hundred and fifty test and training sites covering the main plant formations in the region were undertaken through observations and plant-ecological surveys using the linear transect method. In order to assess the spatial dynamics of the various plant groups over a period of 40 years, the only fairly accurate map of plant formations in the area was used, the phytoecological map produced in 1978 by URBT (Biological and Terrestrial Research Unit).

In 1978, of the nine plant groups mapped, the perennial and para-climacic species identified covered an area of 391240 ha, *i.e*., 83.51 % of the total area of the study region. The steppe dominated by *Stipa tenacissima* L, with an estimated area of 173600 ha (37.06 %), the *Lygeum spartum* L steppe, with an area of 125900 ha (26.88 %, the clear *Artemisia herba-alba* Asso steppe with 48210 ha or 10.29 %, the rest of the plant formations cover only 25.77 % including mixed steppes covering an area of 34810 ha (7.43 %) and matorrals on 32530 ha (6.94 %), the psamphyle group covered a total area of 26410 ha or 5.64%, 75.84% of which was *Thymelea microphylla* Coss. and 24.16 % *Retama raetam* (Forssk.) Webb., and finally the halophilic steppes of the closed depressions covered an area of 18320 ha (3.91 %) and the southernmost steppe formation dominated by *Arthrophytum scoparium* (Pomel) Iljin. occupied 87200 ha (1.86 %) and 87200 ha (1.86%) of the study area respectively (Table 1).

The use of 150 reference points for the validation resulted in an overall accuracy of 83.08 % for the classification of the TM 2018 image, with a Kappa Index of 0.8121. Reading of the statistics in Table 1 and Figure 2, which illustrate the results of the land cover areas for the 2018 image, shows that the largest area of land cover per entity in terms of surface area is occupied by *Stipa tenacissima* L with an estimated surface area of 109862 ha or 23.45 % of the total study area, followed by rangelands with *Lygeum spartum* L with an area of 106631 ha or 22.76 %, psomophytes with an area estimated at 93513 ha or 19.96% and formations with *Artemisia herba-alba* Asso with 46241 ha which represents 9.87 % of the study area, the rest of the plant formations cover only 25.77 % of which the *Retama raetam* (Forssk.) formation *and* the *Arthrophytum scoparium* (Pomel) Iljin. formation extend respectively over a surface area of 35325 ha or 7.54 % and 34 201ha or 7.30 % followed by the halophytes with a surface area of 18412 ha or 3.93% and the matorrals formations which occupy 17194 ha or 3.67 %. Finally the mixed formations which cover 7120 ha or 1.52 % of the total surface area of the study area.

A reading of the statistics in Table 2 shows clearly that the mixed steppe with *Stipa tenacissima* L and *Lygeum spartum* L declined by 63,738 ha, i.e. 3.61 % of its initial area, while the fairly dense mixed steppe with *Lygeum spartum* L and *Artemisia herba-alba* Asoo declined considerably during the study period, to 27 689 ha, i.e. 5.81 % compared with 1978, followed by the steppe with *Lygeum spartum* L and Matorrals of *Juniperus phoenicea* L and *Stipa tenacissima* L, which lost 19 269 ha or 4.11 % and 15 336 ha or 3.27 % respectively of their initial areas, and the open steppe with *Artemisia herba-alba* Asso declined by 1 969 ha or 0.42 %. On the other hand, the psammophilous groups with *Thymelea microphylla* Coss. and *Tamarix africana* Webb.have increased significantly, with an estimated 73 483ha or 15.78 %, as well as the psammophilous grouping with *Retama raetam* (Forssk.) on living dunes and the steppe with *Arthrophytum scoparium* (Pomel) Iljin., *Stipa tenacissima* L and *Launaea acanthoclada* M. which increased by 28 945 ha, or 6.18 % and 25 481ha or 6.18 % respectively and the halophilous groupings with *Salsola vermiculata* L. and *Atriplex halimus* L with 92 ha or 0.02 % of its initial area.

Usually, the following "scale" is used to interpret the obtained value of kappa κ obtained (Landis and Koch, 1977):

Kappa value (κ)	Assessment
< 0	Big disagreement
0,00 - 0,20	Very weak agreement
0,21 - 0,40	Weak agreement
0,41 - 0,60	Medium tuning
0,61 - 0,80	Satisfactory agreement
0,81 - 1,00	Excellent agreement

This is the reading grid proposed by Landis and Koch in 1977 from which it is clear that our first classifications present satisfactory agreements. However, an excellent agreement (kappa equal to 0.8121) is recorded for the classification of the 2018 Landsat image. The phytoecological map drawn up by URBT (1978) provides a fairly accurate overview of the spatial distribution of the main plant formations in the study region. In 1978, esparto grass (*Stipa tenacissima* L*)*, sparte (*Lygeum spartum* L) and white wormwood (*Artemisia herba-alba* Asso) played a dominant role in the landscape. In the 1970s and 1980s, these three species provided 80-90% plant cover (Aidoud *et al*, 2006). They formed the perennial floristic backdrop to the homogeneous orotopographical complex which is the high steppe plains of southern Oran. The steppe with *Lygeum spartum* L is much more heterogeneous and most often appears as a mosaic including various steppe stands. The matorrasl grouping dominated by *Juniperus phoenicea* L and *Stipa tenacissima* L is found on mountain ranges. Steppe formations characterised by the dominance of grasses (*Lygeums partum* L) or chamephytes (*Artemisia herba–alba* Asso) on glacis and foothills, plant formations characteristic of the salty substrates of sebkhas and dayas (*Atriplex halimus* L, *Salsola vermiculata* L.) and steppe formations characterised by the Saharian bioclimate dominated by *Remth* (*Arthrophytum scoparium* (Pomel) Iljin.), (Kaabeche, 2000). Finally, the *Retama raetam* (Forssk.) group colonizing sandy soils and occupies large areas close to inhabited areas and also the edges of living dunes forming dune strips.

Identifying and mapping the spatial distribution of the main plant formations in 2018 makes it possible to assess the dynamics of each formation. This map confirms the observations made in the field concerning a significant decline in some plant groupings, such as the steppe of *Stipa tenacissima* L and the *Lygeum spartum* L *steppe*, which only covered an area of 109 862 ha in 2018, i.e. a rate of 23.45 %, *Arthrophytum scoparium* (Pomel) Iljin. groups covered an area of 34,200 ha in 2018, groups composed of psamophilous species *Thymelea microphylla* Coss. covered an area of 93 500 ha and *Retama raetam* (Forssk.) on living dunes covered an area of 18,400 ha (Table 1).

The strong regression observed during this period is recorded at the level of the rather dense mixed steppe formations of *Lygeum spartum* L and *Artemisia herba-alba Asso*, the steppe with *Lygeum spartum* L, *Stipa tenacissima* L *and Lygeum spartum* L, and the clear steppe with *Artemisia herba-alba* Asso with an overall rate of 14.05 % or a surface of 112665 ha compared to the year 1978. This deterioration can be explained by the over-exploitation of plant resources by expanding sheep population, strong demographic pressure and a period of exceptional drought between 1970 and 1998, characterized by a reduction in rainfall (estimated by various authors between 17 and 22 %) and a lengthening of the drought period (from 1 to 2 months) (Aidoud *et al.*, 2006). This reduction in the annual rainfall in the high steppe plains has a definite impact on the fragility and decline of the esparto grass cover. In addition, the change in the lifestyle of livestock farmers, who have become semi-sedentary with agro-pastoral activities, the increase in the pastoral load on steppe rangelands and intensive illicit land ploughing accelerated by using mechanical tools in the steppe environment, in particular the tractor and the disc plough.

The 2000s were also marked by the launch of agricultural support programs for agro-pastoralists, who cleared the rangelands as they colonizing the deep, clay soils, which are more or less the most fertile. Overall, and despite its exceptional resistance to drought and grazing, several authors confirm that steppe cover, particularly white wormwood, is in serious decline, mainly due to human activity, especially the uprooting and clearing of this species (Benabdeli, 2000).

Several of authors (Aidoud *et al*., 2006), in particular, were moving in the same direction, sounding the alarm by highlighting the increasing decline of the *Stipa tenacissima* L steppes, despite the return of the rain, and questioning the irreversibility of the phenomenon. Benabdeli (2000) noted: "Under the combined effect of overgrazing and drought, the *Stipa tenacissima* L steppe is in an advanced state of degradation, facilitating a process of desertification".

The degradation phase experienced by the *Stipa tenacissima* L formation since 1975, mainly as a result of anthropogenic pressure induced by clearing and development for rain-fed cereal growing, is becoming very worrying. This formation is finding it difficult to regenerate and dying back and disappearing at a worrying rate.

The current state of degradation of the *Juniperus phoenicea* L and *Stipa tenacissima* L scrublands shows overexploitation of woody vegetation. This is explained, on the one hand, by the need for firewood.

Psammophyllous rangelands have increased significantly, by 27.30 % compared with 1978, especially at micro-dune level, as a result of pastoral development work carried out as part of the fight against desertification, carried out by the High Commission for the Development of the Steppe (HCDS) which consist on the one hand of the mechanical and biological fixation of the dunes and the pastoral plantations based on *Atriplex canescens (*Pursh) Nutt*.*, on the other hand by the controlled managed rangelands protected areas of the rangelands in the places affected by the phenomenon of desertification generated during the 80s and 90s.

In the face of this alarming situation, there is an urgent need for a thorough assessment to promote a development and conservation policy based on concerted and participatory planning. This policy must be based on indigenous species. Operations such as the rangeland fencing, planting fodder shrubs and mechanical and biological dune fixation have yielded satisfactory results in the rehabilitation of degraded rangelands. To this end, there is an urgent need to promote these operations in the steppe rangeland development policy.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Spatial distribution of land use classes in 1978 and 2018

N°	Plant groups	Surface area (ha)	
		1978	2018
1	Matorrals of *Juniperus phoenicea* L and *Stipa tenacissima* L	32530	17194
2	Steppe with *Stipa tenacissima* L and *Lygeumspartum* L	173600	109862
3	Fairly densely mixed steppe with *Lygeum spartum* L and *Artemisia herba- alba* Asso	34810	7121
4	Open steppe with *Artemisia herba-alba* Asso	48210	46241
5	Steppe with *Lygeum spartum* L	125900	106631
6	Steppe with *Arthrophytum scoparium* (Pomel) Iljin., *Stipa tenacissima* L and *Launaea acanthoclada* M.	8720	34201
7	Halophilous communities with *Salsola vermiculata* L. and *Atriplex halimus* L	18320	18412
8	Psammophilous groups with *Thymelea microphylla* Coss. and *Tamarix africana* Webb.	20030	93513
9	Psammophilous group with *Retama raetam* (Forssk.) living dunes	6380	35325

Table 2: Changes in the surface area of land use units over the study period (1978 - 2018).

N°	Plant groups	Area (ha)		Difference	
		1978	2018	Area (ha)	%
1	Matorrals of *Juniperus phoenicea* L and *Stipa tenacissima* L	32530	17194	-15336	-3.27
2	Steppe with *Stipa tenacissima* L and *Lygeumspartum* L	173600	109862	-63738	-3.61
3	Fairly densely mixed steppe with *Lygeum spartum* L and *Artemisia herba- alba* Asoo	34810	7121	-27689	-5.91
4	Open steppe with *Artemisia herba-alba*	48210	46241	-1969	-0.42
5	Steppe with *Lygeum spartum* L	125900	106631	-19269	-4.11
6	Steppe with *Arthrophytum scoparium* (Pomel) Iljin., *Stipa tenacissima* L and *Launaea acanthoclada* M.	8720	34201	25481	5.44
7	Halophilous communities with *Salsola vermiculata* L. and *Atriplex halimus* L	18320	18412	92	0.02
8	Psammophilous groups with *Thymelea microphylla* Coss. and *Tamarix africana* Webb	20030	93513	73483	15.68
9	Psammophilous group with *Retama raetam* (Forssk.) living dunes	6380	35325	28945	6.18

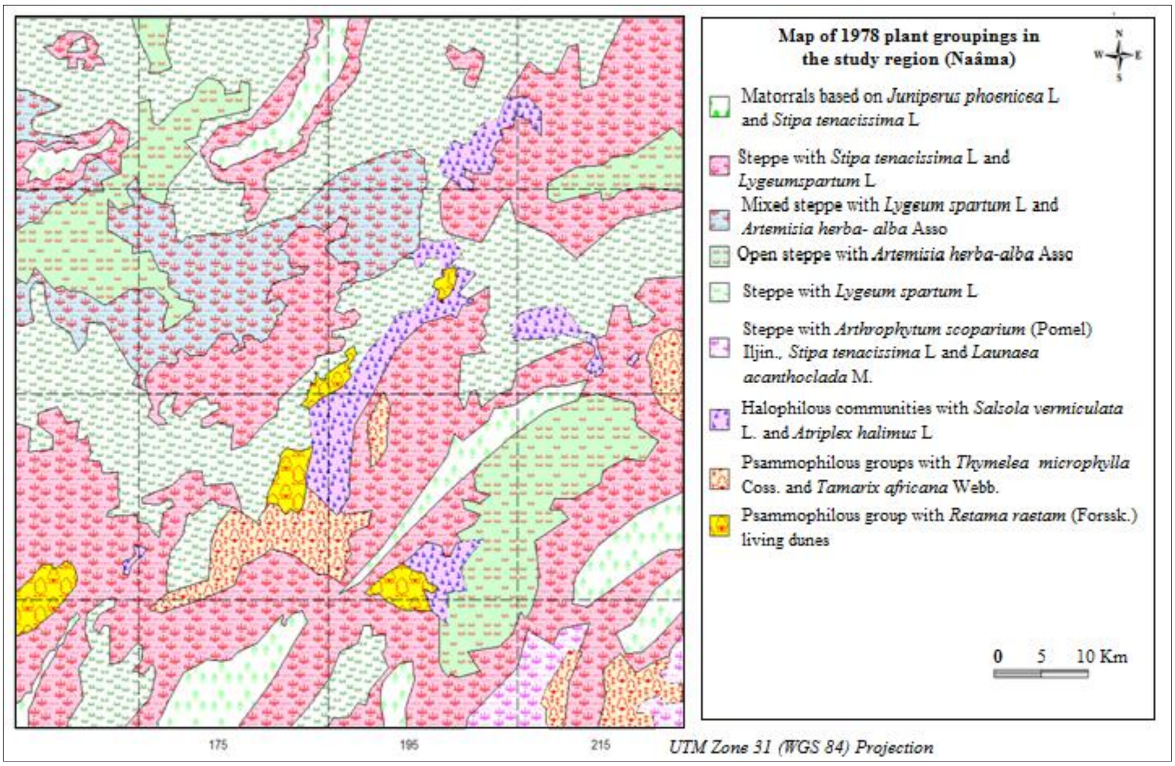

Figure 1: Map of 1978 plant groups in the study area

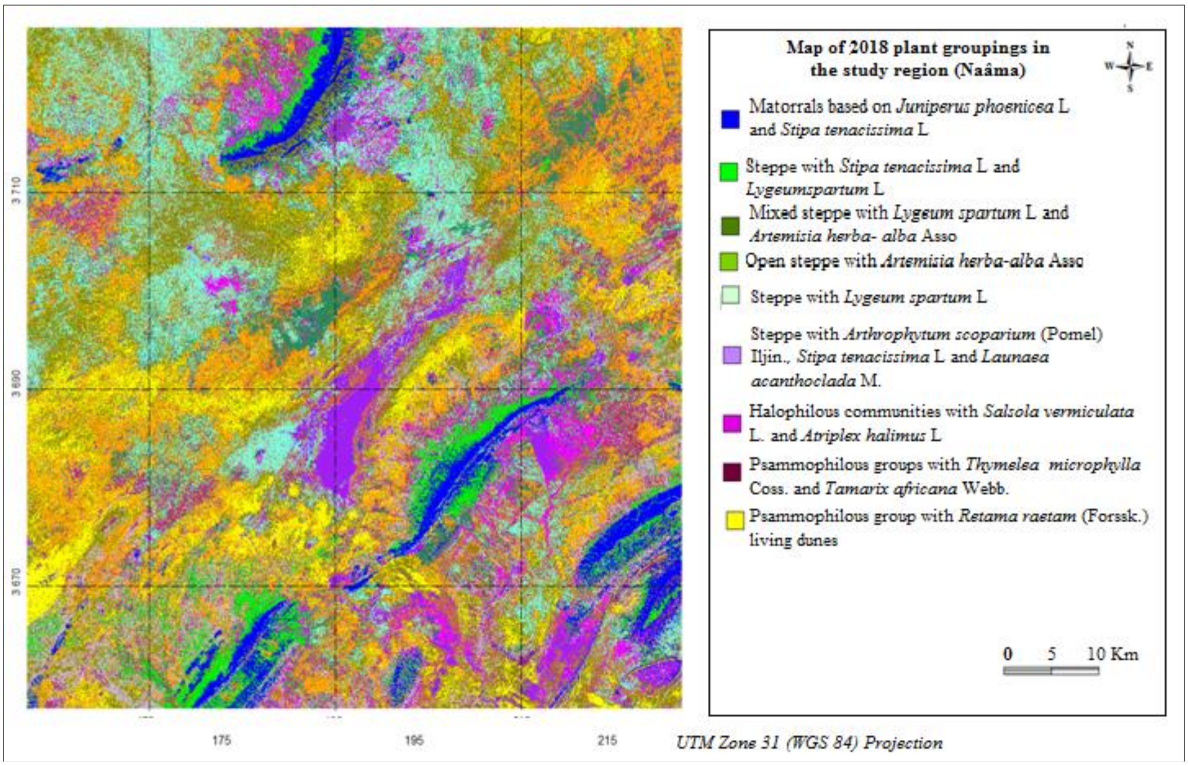

Figure 2: Map of 2018 plant groupings in the study region