



Remote Sensing of Land Cover Dynamics in Arid Steppe: Case of Algeria South-West

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Abstract: Land cover change is the result of complex interactions between social and environmental systems that evolved over a period of time. Climate and biophysical phenomena have long been the main drivers of changes in land surfaces, but at present the human induced activities govern most of changes affecting terrestrial ecosystem. The investigation aims to study the distribution pattern of plants groups that constitute the ecosystem typical of west Algeria and their dynamics as well as to assess method to monitor the degradation process and capability of a system to protect areas earmarked for plant and animal species. The Landsat satellite images were used for mapping the vegetation of the study area at a scale of 1:200,000. The changes were assessed based on the maps obtained from satellite images (Landsat 8) of 2014 and of 1987 (Landsat 5). The results revealed strong decrease in the area of land occupied by steppe of *Stipa tenacissima* and steppe of *Artimesia herba-alba*, which was replaced by three taxa *Thymelaea microphylla*, *Salsola vermiculata* and *Peganum harmala*. Steppe of *Artemisia herba alba* has been reinstated by steppe of *Thymelaea microphylla*, *Salsola vermiculata* and *Lygeum spartum*. Woody species such as *Quercus ilex* and *Juniperus phoenicea* are also characterized and studied.

Key words: Land Cover, mapping, change detection, steppe, landsat, remote sensing.

The southern steppe of Algeria is subjected to ancient climatic and anthropogenic disturbances since 1970s and the important changes that has occurred in the steppe are very important and recorded. The notable among are the decrease in area of this steppe, which is the consequence of paramount degradation of the same. This situation further led to degradation of biodiversity and natural resources and threatening wildlife, flora.

Degradation of the west steppe of Algeria is basically due to begins with an alteration of vegetation resources; changes in species composition, scarce species with high grazing value are the important factors that determines the steppe regressive evolution. Simultaneously, the soil properties in the steppe have also deteriorated. Thematic Mapper (TM) is most commonly used satellite sensors among Landsat series satellite platforms. The spatial and temporal resolution, the availability, the coverage and the overall quality of the Landsat data, provide useful background information for detailed studies on land-use change (Julien *et al.*, 2011; Güler *et al.*, 2007). Numerous methods have been developed

for land cover change detection (Dewan and Yamaguchi; 2009; Siren and Brondizio, 2009). According to (Yuan *et al.*, 1998) the methods for change detection and classification are divided into pre classification and post classification techniques. The pre classification techniques apply various algorithms directly to multiple dates of satellite imagery to generate "change" versus "no change" maps. These techniques locate changes but do not provide information on the nature of change (Singh, 1989; Ridd and Liu, 1998). On the other hand, post classification comparison methods use separate classifications of images acquired at different times to produce difference maps from which "from-to" change information can be generated (Jensen, 2004). Although the accuracy of the change maps is dependent on the accuracy of the individual classifications and is subject to error propagation, the classification of each date of imagery builds a historical series that can be more easily updated and used for applications other than change detection. The post classification comparison approach also compensates for variation in atmospheric conditions and vegetation phenology between dates, since each classification is independently produced and mapped (Yuan, 1998; Yuan *et*

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al., 2005; Coppin *et al.*, 2004). In recent years, new landslide susceptibility assessment method such as support vector machine (SVM) (Micheletti *et al.*, 2011; Yilmaz, 2010). SVM are an alternative nonparametric classifier that offers particular promise for change detection of multiple forest classes because they can handle complex distributions of multi-temporal imagery (Huang *et al.*, 2002).

The objective of this work is to study the distribution of vegetation formations that constitute the ecosystem typical of west Algeria and their dynamics in time and space, as well as to assess methods to monitor the degradation process and a development of a system capable of effectively protecting areas classified for plant and animal species. To this end, it is necessary to make an assessment of the state of the land in general, and of plant cover in particular, which needs to be addressed on priority. As part of this work, in contrast to the present situation, vegetation dynamics studies on Mecheria's steppe was also carried out from 1987 to 2014.

In the present study plant groups were identified and discriminated in the steppe with the analysis of remotely sensed data (Landsat 5 and Landsat 8) using digital processing and field observations, to establish vegetation types, in terms of sensor satellite perception. The Landsat satellite images were used to map the vegetation of the study area

at a scale of 1:200,000. A comparison was then made between the maps obtained from satellite images (1987 and 2014).

Methodology

Study area

The study site was conducted at Mecheria, located in the western high plains of Algeria in the north of Naama province. The study site lies at an altitude between 1070 and 1720 meters. The areas with minimum altitudes (1070-1720 m) are located in northeast and northwest, while the areas with highest altitude (1400 to 1720 m) lies in small pockets in north, south and south east parts.

Study area is surrounded by the mountains of the Atlas Tell to the north and the great Moroccan massifs (over 3000 m) to the west, the inland areas of western Algeria are deprived of rainfall. From a biogeographical point of view, the region belongs to the Mediterranean area, the highlands sector and the area under the Saharan Atlas according to Quezel and Santa subdivisions (Quezel and Santa, 1962).

The average annual rainfall of Mecheria for last 24 years (1984-2010) is 250 mm which explains aridity of the area. Annual climate regime is characterized by two main seasons, a relatively wet and cold season extends from November to April and the hot and dry season from May to October.

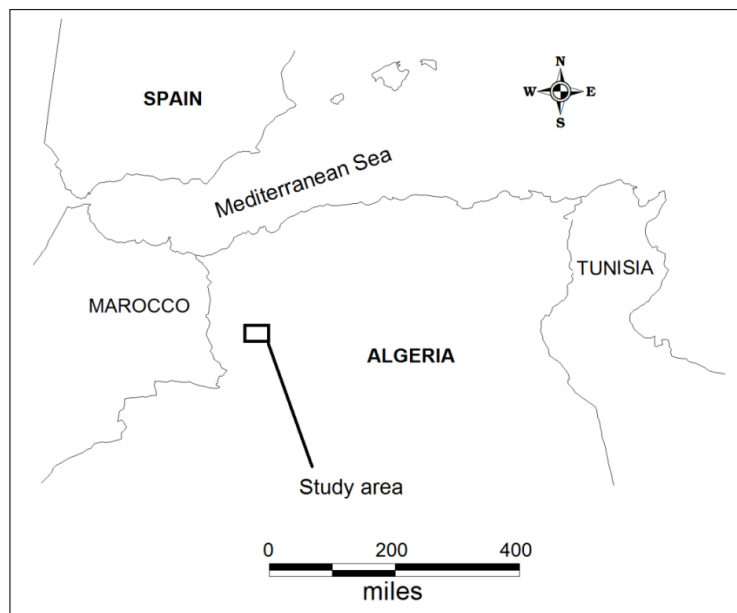


Fig. 1. Localization of study area.

Data processing

Land-cover and land-use change analysis studies using multi-temporal remote sensing data is dependent on accurate radiometric and geometric rectification (Schott *et al.*, 1988; Dai and Khorram, 1999). These pre-processing requirements typically present the most challenging aspects of change detection studies and are the most often neglected, particularly with regard to accurate and precise radiometric calibration and atmospheric correction (Chavez, 1996).

Image to image correction was applied to the TM data through a total of 20 control points were used to establish a geometric relationship between the pixels of the first images over the second image. The images were geo-referenced in the UTM coordinate system (WGS 84) zone 30. The Root Mean Square (RMS) indicates an error of 0.2 pixels between images which is within the required limit (0.50 pixel) to perform change detection between two satellite images (Jensen, 1996).

Atmospheric correction using the method "QUAC" Quick Atmospheric Correction, this method determines atmospheric compensation parameters directly from the information contained within the scene (observed pixel spectra), without ancillary information. QUAC was developed as a simpler alternative to sophisticated atmospheric correction procedures, such as FLAASH, which are based on irradiative transfer models (Bernstein *et al.*, 2005; Bernstein *et al.*, 2006), generally producing reflectance spectra within approximately +/-15% of the physics-based approaches (Bernstein *et al.*, 2005). QUAC is based on the empirical finding that the average reflectance of a collection of diverse material spectra, such as the end member spectra in a scene, is essentially scene-independent.

Classification

Different training sets were delineated for each land cover class and verified through a digital thematic map and through visual interpretation of each images. SVM has advantages of working with fewer prior knowledge, suitability to small size of samples, more robustness to noises (Chi *et al.*, 2008), and higher learning efficiency with greater generalization capacity (Ancona *et al.*, 2006).

Support Vector Machines (SVM) (Janz *et al.*, 2007), installed in the software ENVI 4.7 with a Gaussian radial basis function used in present investigation (Huang *et al.*, 2009; Petropoulos *et al.*, 2010). In this study, the SVMs classifier was applied to the Landsat imagery for mapping the land use/cover of the study area using the training data. Initially the classification key was formulated, which included detailed information on steppe, agriculture, matorral, urban and bare land of the region. The decision to use this classification scheme was based primarily on photo- interpretation of the higher resolution imagery acquired from Google Earth, ground observation and vegetation map established in 1978. Second, training sites representative of each of the above classes were collected from the Landsat imagery following a simple random sampling strategy. Selection of the training sites was primarily guided by the high resolution imagery photo interpretation in Google earth image. The training sites were carefully determined and restricted to homogeneous regions. Approximately more than 300 pixels per class were identified as training data representing the classes defined in the classification scheme. Third, the SVMs algorithm was implemented, using the training sites collected during the previous step.

Change Detection

A quantitative analysis of land use and land cover spatial dynamics was done by comparing two images classified (1987-2014) by change detection statistics method implemented in ENVI 4.7 software, The changes detected using this technology differ significantly from a simple differencing of the two images. While the statistics report does include a class-for-class image difference, the analysis focuses primarily on the initial state classification changes; that is, for each initial state class, the analysis identifies the classes into which those pixels changed in the final state image.

This may be the most common approach to compare data from different sources and dates (Jensen, 2004; Mundia and Aniya, 2006). The advantage of post-classification comparison is that it by passes the difficulties associated with the analysis of images acquired at different times of the year and/or by different sensors (Yuan *et al.*, 2005; Coppin *et al.*, 2004; Alphan, 2003). Moreover, the post classification method

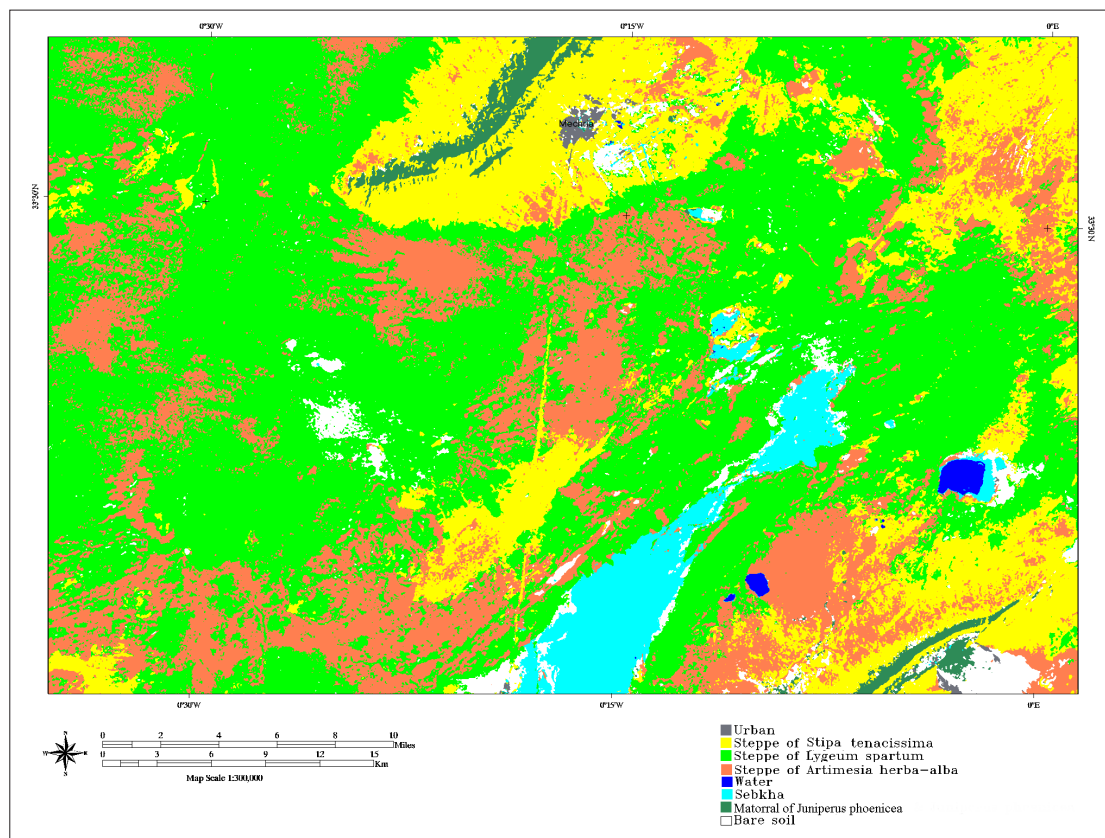


Fig. 2. Land cover map of 1987.

also answers the amount, location, and nature of change (Howarth and Wickware, 1981).

Result and Discussion

Land cover change maps

Two time series land cover maps were prepared by classification of Landsat 5 image of 1987 and Landsat 8 image of 2014, to provide an overview on the distribution of the steppe vegetation in the study area, this classification has identified the following steppe groups (Fig. 2 and 3).

- Steppe of *Stipa tenacissima*
- Steppe of *Lygeum spartum*
- Steppe of *Artemisia herba-alba*
- Steppe of *Peganum harmala*
- Steppe of *Thymelaea microphyla*

The evaluation of the classification accuracy involves comparison of the classified image with field observations. This comparison is usually based on a confusion matrix between the data set (Hirche *et al.*, 2007). Measures

such as correct classification percentage and the kappa coefficient can be derived from confusion matrix elements, are used to express the classification accuracy.

The confusion matrix is obtained by commission to check the proportion of pixels for each theme over estimated that should not belong to that particular class. The total per column is the theme area percentage that has been overestimated. The results showed accuracy percentage for image classification of 1987 is 80% and 87% for the second image (2014).

KAPPA coefficient was 0.74 for classification of 1987 and 0.79 for 2014, which indicates that the classification is more or less accurate with a large concordance.

The land cover map produced from the image 1987 (Fig. 2) gives an overview of the vegetation distribution in the area. Further it showed that the Steppe of *Lygeum spartum* occupies 51% of the surface, followed by steppe of *Artemisia herba-alba* which occupied 23% of surface and by Steppe of *Stipa tenacissima* which cover 18% of the surface.

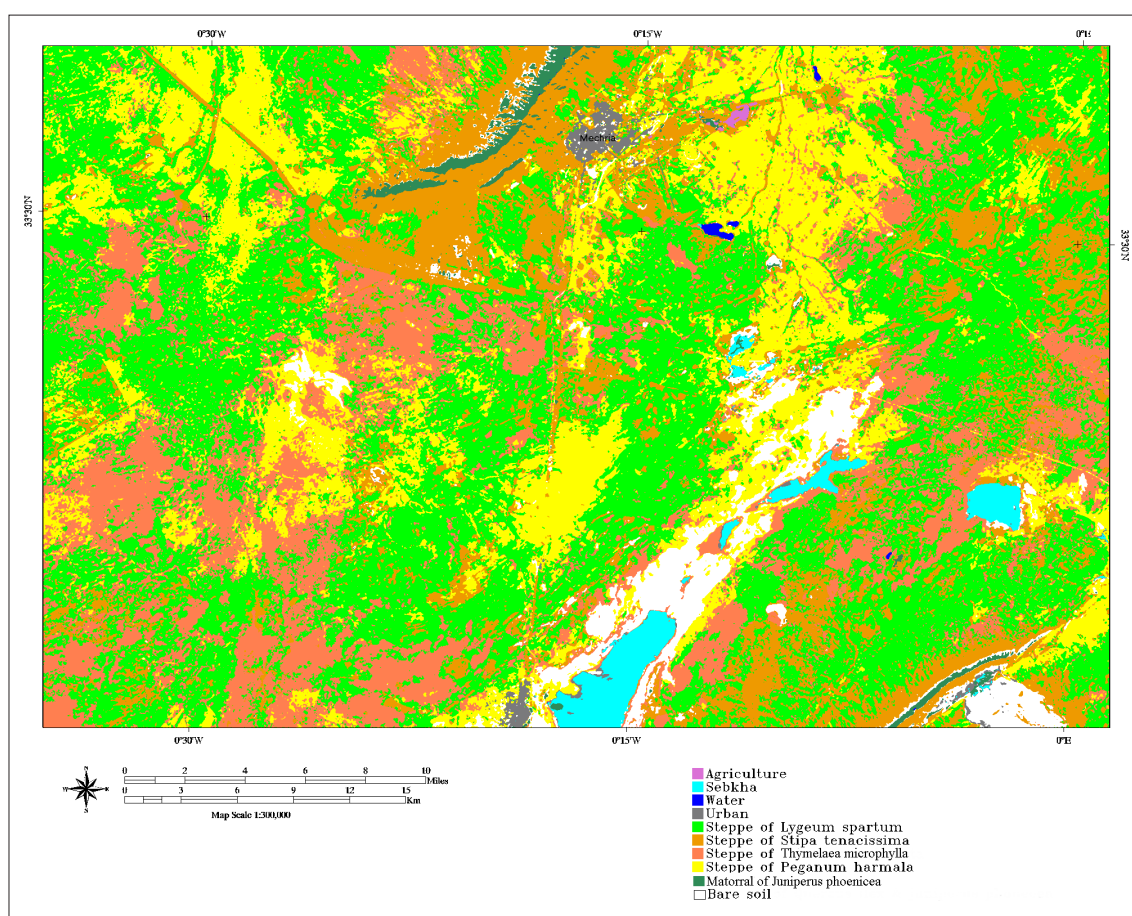


Fig. 3. Land cover map of 2014.

The land cover map derived from the satellite image of 2014 (Fig. 3) showed that majority of the area is colonized by Steppe of *Lygeum spartum* exceeding 822 km² covering 40% of surface followed by *Stipa tenacissima* with 17% surface and 19% of surface covered *Thymelaea microphylla* and steppe of *Peganum harmala* spread over 19% of surface.

The summary of the results of comparison between two land cover maps and net changes in the steppe class for the period from 1987 to 2014 is presented in Table 1.

The land cover change and biodiversity loss characterize the regressive evolution of the entire steppe. Some vegetation groups mapped in 1987 have completely disappeared and were replaced by others such as *Peganum harmala* which are also known as indicator species for degradation of the steppe.

Steppe of *Stipa tenacissima* has lost 65% of its original land; they are converted to steppe of *Lygeum spartum*, *Peganum harmala* and *Thymelaea microphylla*. However, this steppe was

established on the land of another formation known as *Artimesia herba-alba* and *Lygeum spartum*. About 58% of *Lygeum spartum* were converted to *Thymelaea microphylla*, *Peganum harmala* and *Stipa tenacissima*, which has been established on large surface previously covered with *Stipa tenacissima*, in about 98.5 km², with a net increase of 30% over the period of 27 years.

The steppe of *Artimesia herba-alba* lost almost its entire surface and the same surface is used for growing of other species such as *Stipa tenacissima*, *Thymelaea microphylla*, *Peganum harmala*, the last two species are considered as indicator species for the degraded steppe.

During the period (1987 to 2014) the development of *Thymelaea microphylla* and *Peganum harmala* is characterized mainly on the territory of *Artimesia herba-alba*. The matorral of *Juniperus phoenicea* which is located in the mountains of the study area also undergone an intensive regression and lost almost 60% of its area, and transformed into *Stipa tenacissima* and bare soil.

Table 1. Evolution of the main steppe

Original steppe (1987)	Current steppe (2014)	Percentage change	Area (km ²)
<i>Stipa tenacissima</i>	<i>Lygeum spartum</i>	38	141.2
	<i>Peganum harmala</i>	18	68.4
	<i>Thymelaea microphylla</i> and <i>Salsola vermiculata</i>	07	27
	<i>Stipa tenacissima</i>	34	125.8
<i>Artimesia herba-alba</i>	<i>Stipa tenacissima</i>	19.4	92.3
	<i>Thymelaea microphylla</i> and <i>Salsola vermiculata</i>	23.3	111
	<i>Peganum harmala</i>	10	48.1
	<i>Lygeum spartum</i>	45	217.3
<i>Lygeum spartum</i>	<i>Thymelaea microphylla</i> and <i>Salsola vermiculata</i>	23.4	245
	<i>Peganum harmala</i>	23.5	246.2
	<i>Stipa tenacissima</i>	09.4	98.4
	<i>Lygeum spartum</i>	42	440.3
<i>Juniperus phoenicea</i>	<i>Stipa tenacissima</i>	39	12
	<i>Juniperus phoenicea</i>	39.6	12.2
	Bare soil	18	5.5

Causes of land cover change

Steppe pasture change is derived from the interaction of two factors. Natural factors related to the conditions of the physical environment in general and socio-economic factors that promotes human anarchic action on the ecosystem.

Aridity: Algerian steppe is marked by an inter-annual variability of rainfall. The decline in annual rainfall (18-27%) and occurrence of droughts in consecutive years were also observed/recorded in recent decades. Earlier Benabadji and Bouazza, 2000 also showed that the Algerian steppes area characterized by increasing aridity in recent decades.

Traditionally long trips (transhumance) are being practiced by the farmers of frazile and unproductive pasture to protect their pasture from overgrazing. Recently this practice reduced significantly and has been replaced by sedentary livestock farming.

Overgrazing: Overgrazing of the steppe is mainly due to intensive and uncontrolled grazing for extended period with insufficient recovery period. As a result true species have sickly appearance, stunted growth and replaced by less preferred species for animal grazing. The soils of the steppe were also exposed and are more vulnerable to erosion. The presently the total livestock population is

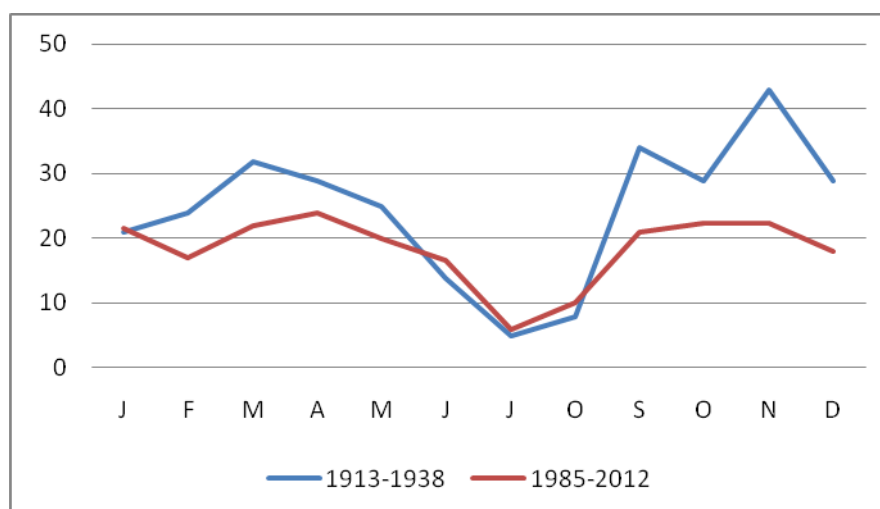


Fig. 4. Soverage monthly rainfall s of study area.

about 1200000 heads consisting of sheep, goat, cow, goats and camels. Furthermore, the herd population and composition also varies from year to year and due to climatic variability and social considerations of livestock based farming community. Overgrazing of the steppe for a longer period the pastoral charges has been increased twice than before, degraded the pasture and forage production is halved (Nedjraoui and Bédrani, 2008). In view of the growing demand of sheep meat products the profitability of livestock farming is completely dependent on availability of quality forage at reasonable price.

Evolution of steppe population: The population of the steppe was 900,000 inhabitants in 1954 and was increased to more than seven (07) million in 1999 (HCDS, 2005). Transhumance or displacement of large amplitude (Azaba; summer transhumance to the stubble of the Tell zones or Achaba; winter transhumance towards north piedmonts of the Saharan Atlas) in the past allowed rational use of natural resources, but presently it concerns hardly for 5% of the steppe population (Nedjimi *et al.*, 2008). The rest of the population became semi-sedentary. Pastoralists have evolved their production system by cultivation cereal crop and sedentarization (Khalidoun, 2000). The main consequence of this transformation of grazing management is the over exploitation of biological resources and land degradation.

The social and biological balance is disturbed strongly by increasing needs of burgeoning population of the steppe. The decrease of the living population in scattered areas and the decline of the nomadic population reflect the importance of the sedentarization that have lived the steppes zones in recent period. It appears that, demographic growth and strong increasingly sedentarization as consequences of increased pressure on resources and human anarchic action.

Conclusion

The balance of the steppe ecosystem is disturbed as manifested by its general degradation of the environment. The unorganized transhumance and overexploitation of pastoral resources with ever increasing livestock population and farm mechanization led to the imbalance of steppe ecosystem which is reflected by degraded

pastures and extended desert landscape. An appropriate pastures management strategies and policy intervention considering potentials and constraints is needed urgently for the use of steppe areas, Recent technologies such as remote sensing and GIS are the important tools for monitoring and assessment of degradation and desertification for better understanding of the cause and effect. The long-term monitoring of the ecological changes that has taken place in steppe provided spatiotemporal data, impact of degradation and desertification on agroecological and socioeconomic changes in the region and helpful for rehabilitation of the degraded steppe and management of natural resources.

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