UNIVERSITI PUTRA MALAYSIA

DROUGHT-EVENTS AND POTENTIAL IMPACTS ON LAND USE/LAND COVER DYNAMICS BASED ON AVHRR DATA OF 1992-2003 FOR CENTRAL IRAN

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BY

AHMAD MOKHTARI

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

Dedicated:

To my dearest parents

To my beloved wife

To my precious children

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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Chairman: Professor Shattri B. Mansor, PhD

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This project was implemented on Zayandeh-Rud basin which is one of the most important and strategic regions of Iran. The continuing growth of urban population and rapidly increasing demand on land and water resources have led to a competition on land and water between the industrial and the agricultural sectors. Although drought is one of the most important hazards affecting land use/land cover in Zayandeh-Rud catchment; however, there is a confusion to explain the main root causes of land use/cover change and consequently land and water degradation. Therefore, the main objective of this research set to evaluate the potential drought-events impacts on land use/cover dynamics over a 10-year period (1992-2003). At the first phase, primarily, Standard Precipitation Index (SPI) computed for 1970-2003 rainfall records of weather gauge stations. Then, the methods with the best performances depicted to produce the spatio-temporal SPI drought index layer. At the second phase, a seasonal-based classification algorithm for AVHRR

(Advanced Very High Resolution Radiometer) data developed to enhance the classification accuracy. The model works based on the seasonal values of Normalized-Difference Vegetation Index (NDVI) correlated to vegetation canopy cover. The algorithm was compared with the maximum likelihood supervised classification algorithm. Results demonstrated an increase at overall accuracy from 74.34% (in the maximum likelihood), to 90.07% (in the seasonal-based method) and the Kappa index from 70.58%, (in maximum likelihood), to 88.8% (in seasonal-based method). Based on the final statistical analysis, in the final phase, SPI drought index showed statistically significant relationship to change in rain fed areas (R^2=0.82), barren land areas (R^2=0.51), mixed garden and irrigated areas (R^2=0.49), water bodies area (R^2=0.45) and rangelands under both medium and good conditions (R^2=0.42). Nevertheless, statistically, no significant relationship found for forest and reforestation areas (R^2=0.28), rangelands under fair to poor conditions (R^2=0.12) and irrigated cropland areas (R^2=0.00). In conclusion, based on the research results, the potential key factor of landscape change at the most part of Zayandeh-Rud catchment recognized as the natural drought. However, in forest and reforestation areas, rain fed croplands and rangelands under both fair and poor conditions, other driving factors are in priority. In such areas, human activities in different aspects, such as over grazing in poor rangeland area, clear cutting and deforestation in forestland areas and land cover disturbances by natural rangelands deformation to low performance rain fed croplands, might be main cause of land disorders in the research area.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan Ijazah Doktor Falsafah

KEJADIAN KEMARAU DAN POTENSI IMPAK TERHADAP KEDINAMIKAN GUNA TANAH/LITUPAN TANAH BERDASARKAN DATA AVHRR BAGI TAHUN 1992-2003 DI KAWASAN TENGAH IRAN

Oleh

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Projek ini dilaksanakan ke atas lembangan Zayandeh-Rud yang merupakan salah satu kawasan yang paling penting dan strategik di Iran. Pertumbuhan populasi bandar yang berterusan dan permintaan yang meningkat dengan pesat terhadap tanah dan sumber air telah menyebabkan persaingan terhadap tanah dan air antara sektor industri dan pertanian. Walaupun kemarau merupakan bahaya yang paling utama yang menyebabkan penggunaan tanah/litupan tanah kawasan tadahan di Zayandeh-Rud; namun, terdapat kekeliruan untuk menerangkan penyebab utama perubahan penggunaan tanah /litupan tanah dan seterusnya degradasi tanah dan air. Oleh sebab itu,objektif utama penyelidikan ini adalah untuk menilai impak berpotensi kejadian kemarau terhadap penggunaan tanah/litupan dinamik di sepanjang tempoh 10 tahun (1992-2003). Bagi tempoh fasa pertama, terutamanya, Indeks Presipitasi Standard (SPI) yang dihitung untuk rekod hujan bagi tahun 1970-2003 bagi stesen tolok cuaca. Kemudian, kaedah yang berprestasi terbaik digambarkan bagi menghasilkan lapisan indeks kemarau ruang masa SPI. Pada fasa kedua, algoritma klasifikasi berdasarkan musim bagi data AVHRR (Advanced Very

High Resolution Radiometer) dihasilkan untuk merangsang ketepatan klasifikasi. Model tersebut berfungsi berdasarkan nilai bermusim Indeks Tumbuh-tumbuhan Perbezaan Normal (NDVI) yang berkorelasi bagi litupan kanopi tumbuh-tumbuhan. Algoritma dibandingkan dengan algoritma klasifikasi seliaan kebolehjadian maksimum. Hasil dapatan memperlihatkan peningkatan bagi keseluruhan ketepatan daripada 74.34% (kebolehjadian maksimum), kepada 90.07% (bagi kaedah berdasarkan musim) dan Indeks Kappa daripada 70.58%, (kebolehjadian maksimum), kepada 88.8% (bagi kaedah berdasarkan musim). Berdasarkan analisis statistik terkini, pada fasa akhir, indeks kemarau SPI memperlihatkan hubungan yang signifikan secara statistik terhadap perubahan di kawasan umpanan hujan (R^2=0.82), kawasan tanah gersang (R^2=0.51), taman campuran dan kawasan berpengairan (R^2=0.49), kawasan berair (R^2=0.45) dan padang gembala di bawah kedua-dua kondisi medium dan baik (R^2=0.42). Walau bagaimanapun, secara statistik,didapati tidak terdapat hubungan yang signifikan bagi kawasan hutan dan penghutanan semula (R^2=0.28), padang gembala di bawah kondisi sederhana dan buruk (R^2=0.12) dan kawasan tanaman berpengairan (R^2=0.00). Kesimpulannya, berdasarkan hasil dapatan kajian, faktor utama berpotensi perubahan landskap di kebanyakan bahagian tadahan Zayandeh-Rud telah dikenal pasti sebagai kawasan kemarau semula jadi. Walau bagaimanapun, di kawasan hutan dan penghutanan semula, kawasan umpanan hujan, dan padang gembala di bawah kondisi sederhana dan buruk, faktor lain merupakan faktor penggerak utama. Di kawasan tersebut, aktiviti manusia dari aspek yang berbeza, seperti terlebih ragutan di kawasan padang gembala yang buruk, tebangan habis dan penghutanan semula di kawasan hutan dan gangguan litupan tanah oleh deformasi padang gembala semula jadi kepada prestasi rendah di kawasan umpanan hujan, mungkin merupakan penyebab terjadinya kekacauan di kawasan yang dikaji.

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Ahmad Mokhtari

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LIST OF ABBREVIATIONS

AVHRR	Advanced Very High Resolution Radiometer
CMI	Crop Moisture Index
EARC	Esfahan Agricultural Research Centre
FAO	Food and Agriculture Organization
GIS	Geographic Information System
IAERI	Iranian Agricultural Engineering Research Institute
IFOV	Instantaneous Field-Of-View
ILWIS	Integrated Land and Watershed Information System
IRIMO	Islamic Republic of Iran Meteorological Organization
ISA	Iran Space Agency
IWMI	International Water Management Institute
LU/LC	Land Use/Land Cover
MAE	Mean Absolute Error
MBE	Mean Bias Error
NCC	National Cartographic Center (of Iran)
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
OJA	Organization of Jihad-e-Agriculture
PDSI	Palmer Drought Severity Index
PNI	Percentage of Normal Index
RDI	Reclamation Drought Index
RFOV	Reduced Field of View
SPI	Standardized Precipitation Index
UNESCO	United Nations Educational Scientific and Cultural Organization
USGS	United States Geological Survey
WECD	World Commission on Environment and Development
WMA	Weighted Moving Average
WMO	World Meteorological Organization

LIST OF NOTATIONS

- *AVG (n)* — ***n*** Years Average isohyet map
- **C** — Sill in Variogram model
- C_0 — Nugget effect in Variogram model
- *d* — Water deficiency
- *Di* — Distance between the estimated point from the measured point
- **E** — Potential Evaporation
- E_o — Observed Value
- E_s — Estimated Value
- **GSD** — Grow Season Data
- **H(x)** — The cumulative probability
- I_a — Thornthwaite Aridity Index
- I_h — Humidity Index
- *M* — Mean of the maximum temperatures of the hottest month
- *m* — Mean of the minimum temperatures of the coldest month
- **MAE** — Mean Absolute Error
- **MBE** — Mean Bias Error
- *n* — Water need
- *N* — Number of data records
- *N(h)* — Number of pairs at each lag distance
- **NSD** — Non-grow Season Data
- *P* — Annual precipitation in millimetre
- *PET* — Potential evapotranspiration in millimetre per day
- P_i — Monthly precipitation
- P_m — Annual precipitation mean
- *Q* — Pluviometric quotienti in Emberger equation
- **r** — Average monthly relative humidity
- **R (or *h*)** — Range of influence in Variogram model
- *RAIN (i)* — Isohyet map values
- *s* — Water surplus
- *SD (n)* — N years precipitation records Standard deviation
- $SPI_{Drought}$ — Drought map of year (i)
- **T** — Mean annual temperature in degree a Centigrade
- **t** — Average Monthly Temperature
- *x* — Precipitation amount

- ***Z (x)*** Variable value in (x) distance
- ***Z(x)*** Estimated grade
- ***Z(x+h)*** Variable value in ($x+h$) distance
- ***Z(xi)*** Sample grade of i_m
- ***Z**** Estimated value
- Z_i Observed value around the intended Point
- $\Gamma(\alpha)$ Gamma function
- α Shape parameter
- β Scale parameter
- λ_i Weight or importance of the variable dependent on i_m

CHAPTER 1

INTRODUCTION

Among the natural incidents that are affecting the human populations in the recent decades, droughts have been higher in number and frequency in comparison to other events (Bryant, 1991). Likely, given the grading system of natural events, which is based on such parameters as the severity, continuity and the extent of the area inflicted, the drought has ranked the first in the past years (Table 1.1).

Drought has a constant gradual effect and it happens in a long-term period, accompanied by such parameters as high temperature, relative moisture, and severe winds, aggravating the severity of the drought. By taking precautionary actions to manage the drought, it will be possible to reduce the aftermaths. This phenomenon can occur in any region, inflicting humans and the environment although it may spread differently. Unlike aridity, which is a permanent climatic phenomenon, the drought occurs in dry and wet regions which have a normal natural climate (Bordi & Sutera, 2004).

In addition, drought is also a creeping and mysterious phenomenon, and its nature has not been fully detected in comparison to other natural incidents (Sene, 2010). Moreover, since it inflicts serious damage and destructive effects from which there is no escape for humans, the continuation of the drought has given rise to the establishment of a warning mechanism in the field of danger management.

Table 1.1 Ranking, characteristics and impacts of the main hazards
(Bryant, 2005)

1 – largest or most significant 5 – smallest or least significant

Rank	Event	Number of Degree of severity	Length of event	Total areal extent	Total loss of life	Total economic loss	Social effect	Long term impact	Suddenness	Associated hazards
1	Drought	1	1	1	1	1	1	1	4	3
2	Tropical cyclone	1	2	2	2	2	2	1	5	1
3	Regional flood	2	2	2	1	1	1	2	4	3
4	Earthquake	1	5	1	2	1	1	2	3	3
5	Volcano	1	4	4	2	2	2	1	3	1
6	Extra tropical	1	3	2	2	2	2	2	5	3
7	Tsunami	2	4	1	2	2	2	3	4	5
8	Bushfire	3	3	3	3	3	3	3	2	5
9	Expansive soils	5	1	1	5	4	5	3	1	5
10	Sea-level rise	5	1	1	5	3	5	1	5	4
11	Icebergs	4	1	1	4	4	5	5	2	5
12	Dust storm	3	3	2	5	4	5	4	1	5
13	Landslides	4	2	2	4	4	4	5	2	5
14	Beach erosion	5	2	2	5	4	4	4	2	5
15	Debris avalanches	2	5	5	3	4	3	5	1	5
16	Creep &	5	1	2	5	4	5	4	2	5
17	Tornado	2	5	3	4	4	4	5	2	5
18	Snowstorm	4	3	3	5	4	4	5	2	4
19	Ice at shore	5	4	1	5	4	5	4	1	5
20	Flash flood	3	5	4	4	4	4	5	1	5
21	Thunderstorm	4	5	2	4	4	5	5	2	4
22	Lightning strike	4	5	2	4	4	5	5	1	5
23	Blizzard	4	3	4	4	4	5	5	1	5
24	Ocean waves	4	4	2	4	4	5	5	3	5
25	Hail storm	4	5	4	5	3	5	5	1	5
26	Freezing rain	4	4	5	5	4	4	5	1	5
27	Localized strong	5	4	3	5	5	5	5	1	5
28	Subsidence	4	3	5	5	4	4	5	3	5
29	Mud & debris	4	4	5	4	4	5	5	4	5
30	Air supported	4	5	5	4	5	5	5	2	5
31	Rock falls	5	5	5	5	5	5	5	1	5

Drought is one of the most awful natural catastrophes in the dry and semi-dry regions. There are different groups of people who need water such as farmers, watershed and reservoir managers, structure designers and managers of water ponds, irrigation programmers and industry owners.

However, these people are interested in having a reliable rain forecast and the status of the water reservoirs, in the coming months. In fact, the ultimate goal of hydrological modelling or ecological research on vegetation cover, which the recent thesis is among them, is removing the ecological crises and the hazards which threaten human and his safety (Sene, 2010; Steedman, 1994). Therefore, The analysis of the water shortage process and its impacts on the reduction of the incentive to human landscape change and the motive to shift the use of the forests, rangelands and reserved areas to agricultural and housing land are of the crucial issues which is dealt with, by this research.

In this thesis, potential drought-events impacts on land use/ land cover dynamics monitored and evaluated over a 10-year period (1992-2003). In order to reach the goal, a seasonal based classification algorithm developed for the very high resolution AVHRR (National Oceanographic and Atmospheric Administration – Advanced Very High Resolution Radiometer) data. Indeed, the algorithm, not only enabled researcher to map the land use/cover changes in arid and semi-arid areas more accurately, but also, it used as an automated script within the thesis project framework for time series land use/land cover mapping. Meanwhile, the most accurate deterministic and stochastic spatial data analysis models for the SPI drought index is determined by evaluation of different surface interpolation and zonation methods for the research period.

1.1 Drought and Aridity

Drought is defined as an unexpected reduction of rainfall for a certain period of time in an area which is not necessarily dry. The amount of this reduction is in such a way that the normal trend of growth is hampered (AFED, 2008). Although drought is not a permanent feature of an area, it can happen in any climatic pattern (Mishra & Singh, 2010). Though, recurrent droughts can lead to a permanent feature of an area, resulting in aridity (D. A. Wilhite, M. Hayes, C. Knutson, & K. H. Smith, 2000).
In contrast, aridity explained as a permanent feature of the climate in an area. It is defined as a lack of sufficient rain for the growth of plant life in that particular area (Salvati, Perini, Sabbi, & Bajocco, 2011). In other words, aridity is a shortage of water according to the hydrological and climatic conditions in a certain area considering the social, ecological, and geological features of that particular area (Medugu, Majid, & Choji, 2008).

There are many different factors, which create arid climate. The most important factors, such as distance from the sea, ocean currents, direction of prevailing winds, relief, proximity to the equator, the El Nino phenomenon and human activity (has recently been accepted by the scientists) which are the factors determining the climate everywhere can be named as the dry areas which form the climate all over the globe (Stevens, 2011).

Meanwhile, UNESCO (1989)uses the bioclimatic index to differentiate the dry areas (Hill & Mutanga, 2009). According to this index, which is shown in Equation 1.1, the areas can be categorized into four different groups, as shown in Table 1.2 below (Mainguet, 1999; Motroni, Canu, Bianco, & Loj, 2009).

$$A = P/ETP \tag{1.1}$$

Where:

P is the annual precipitation in millimetre,
ETP is the potential evapotranspiration in millimetre per day, and
A is the bioclimatic index for aridity.

Table 1.2. Arid zones classification and the main characteristics
(Adapted from Motroni *et al.*, 2009)

Bioclimatic Zone	P/ETP UNESCO range
Arid zones	$P/ETP < 0.3$
Semi-arid zones	$0.3 \leq P/ETP \leq 0.5$
Sub-humid zones	$0.5 < P/ETP \leq 0.75$

Other organizations and researchers have also set other methods with specific descriptions which are most important the ones, as presented in Table 1.3 (Guevara & Milla, 2007; Middleton & Thomas, 1997; Tricart, 1972; UNESCO, 1977).

Table 1.3. Some of the most important Aridity Indices

Method	Year	Comment	Suggested Equation
Köppen	1910	The system is based on the concept that native vegetation is the best expression of climate	—
Köppen	1918	Arid regions were defined as places where the annual rainfall accumulation is defined as limited (e.g. 200 mm/year).	—
Köppen	1926	Arid regions were defined as the places where the annual rainfall accumulation (in centimetres) is less than *R*/2	R= 2*T — if rainfall occurs mainly in the cold season
			R= 2*T+14 — if rainfall is evenly distributed throughout the year
			R= 2*T+28 — if rainfall occurs mainly in the hot season
de Martönne	1926	De Martonne's aridity index gives good results when annual precipitations are I = P (T+10).	I=P(T+10)
Emberger	1933	Emberger's method uses ***m***, the mean of the minimum temperatures of the coldest month, and the pluviometric quotient' ***Q*** reached by dividing the precipitation ***P*** by the product ((M+m)/2)/(M-m)), where ***M*** is the mean of the maximum temperatures of the hottest month, correlated with a profound study of the vegetation of the Mediterranean region giving finely particularized results which allow the preparation of large-scale maps.	((M+m)/2)/(M-m)
Ivanov	1943	Precipitation to Evaporation Ratio (E = Potential Evaporation, t = Average monthly temperature, and r = average monthly relative humidity)	$I = P/\sum E$ $E=0.001(2.5+t^2)(100-r)$
De Martönne	1942	In 1942, de Martonne amended the formula by including a representation of the total average rainfall (P in mm) and average temperature (t in °C) of the driest month. The formula thus became $\frac{\frac{P}{T+10}+\frac{12p}{t+10}}{2}$ giving values of less than 5 for the Sahara and Death Valley in California.	$\frac{\frac{P}{T+10}+\frac{12p}{t+10}}{2}$
Thorntwaite	1948	I_h and I_a are indices of humidity and aridity respectively, *s* is water surplus, *d* is water deficiency, and n is water need. Moist climates have positive values of I_m, and dry climates have negative values.	$I_h = 100\ s/n$ $I_a = 100\ d/n$ $I_m = I_h - 0.6\ I_a$ $I_m = (100s - 60d)/n$
Goussen	1955	Defined based on the severity and number of dry months (i.e. the relationship between temperature and precipitation).	$P \leq 2T$ $P/\sum E$
UNESCO	1979	UNESCO (1979) proposed a method for aridity mapping from the ratio of precipitation (P) to potential evapotranspiration (PET)	AI = P/PET

1.2 Driving Factors to Land use/Land cover Dynamics

Numerous complicated factors control vegetation cover upon the earth surface. Subsidiary to the width range of endogenic, exogenic, natural and anthropogenic agents is the main reason of high degree of sensibility of the vegetal cover (Propastin & Kappas, 2008). Similarly, a large number of factors, such as climate, geology, soil characteristics, underground water regime and human activities, made Vegetation cover and the subsequence land use/land cover sensible to unsustainability in Zayandeh-Rud catchment, especially in its vast arid and semi-arid parts. However, high agricultural water use and growing human population and industry, together with droughts in the Zayandeh-Rud river catchment have made water resource management a critical issue in the region (Madani & Mariño, 2009; Morid, Massah, Alikhani, Mohammadi, & Lasage, 2003).

Analysis of land use change processes requires a three level approaches: determination of the spatial and temporal pattern of change, site studies to understand the driving forces and dynamics, and comparative analyses and modelling to identify the broad factors affecting land use change (Olson, Maitima, Bart, Campbell, Gichohi, Misana, Mbonile, Mugisha, Tukahirwa, & Reid, 1999; Sulieman & Buchroithner, 2007). Accordingly, in the present study, first, an attempt performed to recognize the spatio-temporal pattern of land use/land cover units during the study period. Then, a broad site studies performed to figure out the main key factors of landscape changes. Finally, different comparative analysis and modelling carried out to determine the main key determine the main element of land use/land cover upon the study area. In fact, the main factors of land use land cover changes in the research area generally can be categorized as the changes due to drought-events and the alterations because of other driving factors such as human impacts.

1.2.1 Drought Impacts

Drought, as a natural disaster, is recognized to has clear impacts on environment and natural landscapes (D. A. Wilhite, M. J. Hayes, C. Knutson, & K. H. Smith, 2000). In fact, environmental losses are the results of damaging plant and animal species, wildlife habitat, and air and water quality, forest and range fires, degradation of landscape quality, loss of biodiversity; and soil (Briggs, O'Hagan, & North East AgCare Incorporated, 2005).

Some of the effects are short-term and conditions quickly return to normal following the end of droughts. Other environmental effects linger for some time or may even become permanent. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity of the landscape. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality have forced public officials to give greater attention and resources on these effects (Intergovernmental, 2007). Furthermore, Sivakumar and others (2005) categorized the impacts of drought into four groups of economic, environmental, social, and agricultural. Moreover, they claimed that, in large areas, the effects of droughts are less tangible in comparison to other natural disasters. Correspondingly, Yevzevich and others (1975) have classified the general effects of the drought on the basis of the scale of the study as presented in Table 1.4.

Table 1.4. General effects of droughts in different scales

Scale	Impacts of drought
Global	Hunger and famine, migration or relocation, social conflict and war.
National	National health problems, starvation, economical challenges, increased governmental supports to formers, malnutrition, and dehydration.
Regional	Regional crisis and instability increase in unemployment, and damages in regional economic sectors.
Agricultural areas	Migration or relocation, decrease in income, insolvency.

Water is the most important, and recently, strategic matters in Iran, where is partly located in arid and semi-arid regions (Committee on U.S-Iranian Workshop on Water Conservation, Recycling, Office for Central, Eurasia Development, Cooperation, & National Research, 2005; Karamouz & Araghinejad, 2008). There are many reasons why arid lands, such as most parts of Zayandeh-Rud catchment, are more sensitive to drought impacts. In fact, it could be possible to conclude mainly in two major reasons. The first reason is the low average of the annual precipitation, along with its high changes, which discourage any certainty on the precipitation from season to season and year to year. The second reason is that the spell of droughts in dry areas is longer. In different years, nonetheless, droughts have a slower pace (Asafeh, 2003; Illius & O'Connor, 1999; Mokhtari, Mansor, Mahmud, & Helmi, 2011)

1.2.2 The Other Agents Impacts

Vegetation cover conditions and its dynamics can be explained by the joint effect of controlling factors (Cao, Xu, Chen, Li, Yang, Hong, & Li, 2012). In general, vegetation cover reacts very sensitive on drought, particularly in dry regions (Taylor, Lambin, Stephenne, Harding, & Essery, 2002). If the response of vegetation to wet and dry periods remains constant, increase/decrease of vegetation activity should exactly reflect changes in the amount of precipitation. However, other forces such as human impact will considerably alter the durability of vegetation response to climate factors (Ellis, 2011; Wang, Tiyip, Ding, & Luo, 2009; Zhi-qiang & Jian-fei, 2009). Natural vegetation cover distribution can be seen in change of its response to climate. That is, a stronger response of vegetation to climate may indicate an improvement of vegetation conditions, while a weaker response may indicate a vegetation cover degradation by non-climatic factors for instance human impact (Veron, Paruelo, & Oesterheld, 2006).

The anthropogenic activities not only may lead to reduce the natural vegetal cover, but it also, can be the main agent to the soil loss by erosion and environmental degradation (Abdel Rahman & Sadek, 1995; Williams, McCarthy, & Pickup, 1995). Inattentive human activity is the most important reason to natural resources destruction and ecological unsustainability (Salvati *et al.*, 2011; Westra, 2009) .Based on Dinpanah and Lashgarara (2008), more than 100 million hectares of land resources in Iran are unsustainable, because of irresponsible human activities. They claim that, such activities have been led to following negative consequences:

- The destruction of plant coverage,
- Misuse of the ecological potential of water and soil resources,
- Lack of balance between livestock and range, and
- Lack of environmental controls.

1.3 Satellite Remote Sensing Application to Drought Monitoring and Land use/Land cover Studies

The analysis of vegetation is one of the most fundamental applications of remotely sensed satellite imagery (Lawrence and Ripple, 1999). Investigation of relations between vegetation patterns and its explanatory factors is an object of applications of remote sensing at regional and global scales (Propastin *et al.*, 2008). The Normalized Difference Vegetation Index (*NDVI*) is established as a general surrogate for many conditions of vegetation cover such as over-ground canopy cover (Buermann, Wang, Dong, Zhou, Zeng, Dickinson, Potter, & Myneni, 2002; Tucker & Sellers, 1986). Remotely sensing derived NDVI data have been successfully used for monitoring of vegetation dynamic and environmental changes at regional and global scales (Kawabata, Ichii, & Yamaguchi, 2001; Tucker, Slayback, Pinzon, Los, Myneni, & Taylor, 2001; Xiao & Moody, 2004), detection of droughts (Kogan, 1997), desertification and land degradation studies (Thiam, 2003; Wessels, Prince, Frost, & van Zyl, 2004).

One of the most important applications of remote sensing data is land use/land cover mapping. In order to go through the main objective of the thesis, basically, it is better to review on land use/land cover terms from remote sensing point of view. Technically, the term land use refers to, how the land is being used by human being. Hence, land cover refers to the biophysical materials found on the land (Jensen, 2007). For example, a national park may be used for recreation but covered by coniferous forest, therefore in classification it may classify as recreation area in the land use map, or classify to coniferous forest in land cover map, depends on the study aims.

1.4 Statement of the Problem

The Zayandeh-Rud is one of the most important and strategic river basins in the central of Iran. The basin covers an area occupied by more than three million people and it is a cornerstone in Iran's agriculture and industry. The continuing growth of urban population and the recent, rapidly increasing demand on water for industrial uses have led to a competition on water between the industrial and the agricultural sectors. In addition, increase in land price in the study area especially, in the west upstream areas leads an aggressive occupation from the farm areas to the national natural resources areas and bring about change in land utility, land use and consequently the land cover.

There is a confusion to explain the root causes of land use/cover change and consequently land and water degradation between the natural resources and environmental experts, in one hand, and local land managers, on the other hand. Environmentalist and natural resources fans based on the daily observations and every day's experiences believe that, the main reason of land use/cover change in the study area is human capturing activities in order to increase the ownership areas. However, most of the government agents and local land managers, address different factors like lake of enough available water resources. In this condition, drought is claimed to be the main cause of serious damage to the water resources and subsequently land use/cover in the study area. Therefore, this investigation has been done to clarify the effect of drought on land use/cover change in the study area to judge scientifically about the main root cause of landscape degradation in the research area.

1.5 Objectives

The general objective of this study is: 'To monitor and assessment of potential drought-events impacts on land use/ land cover dynamics of central Iran based on NOAA AVHRR data of 10-years period (1992-2003)'. The specific research objectives of this study are as the following:

- To provide the most accurate spatial data analysis model for the SPI drought index surface interpolation and zonation model upon the study area.
- To develop a seasonal based classification suitable for low spatial resolution satellite data in the arid and semi-arid areas. algorithm to increase accuracy and reliability
- To monitor the drought periods variations and land use/cover changes in order to clarify the real drought impacts on agricultural lands and natural resources in the study duration.

1.6 Hypothesis

This investigation is done to clarify the potential impacts of drought on land use/cover dynamics in the study area, and to judge scientifically about the following hypothesis:

"Drought is the main potential factor of dynamics in landscape in the research area"

1.7 Scope of the Study

The scope of the present study is as follows:

- Different spatial interpolation methods such as nearest point, weighted moving average and kriging will be tested to find out the models with the best performance for each year.
- Different remote sensing approaches and image processing methods such as supervised classification and NDVI transformation will be examined on AVHRR data to produce the most accurate time series land use/land cover maps.
- Time series land use/land cover changes will be compared among the SPI drought index variations, graphically and statistically.

1.8 Thesis overview

The dissertation arranged to describe different phases of research plan properly. Therefore, the progress steps of this thesis explained in six chapters as following:

Chapter 2, provides a brief describe of the study area, at first, and then went through the literature review of definitions. In addition, this chapter reviewed the concepts of drought, land use/land cover mapping and their monitoring.

The used datasets as input data and applied analysis is considered on **Chapter3.** In this chapter, first the used weather data and remotely sensed images are described. Then, the processes which are took place to produce spatio-temporal SPI index is presented in details. Next, the methods to produce time series land use/land cover maps and a new approach to increase classification accuracy by using seasonal AVHRR data is explained. Finally, the flowchart of the whole research steps of the thesis is presented and elucidated.

In **Chapter 4**, the results of methodology implementations are illustrated. The chapter composed to present results of methodology progress stage by stage. Therefore, initially, outcomes of spatial data analysis on SPI drought index to produce spatio-temporal drought layer, is presented. Secondly, outputs of image processing from pre-processing, processing and post-processing steps in order to generate temporal landscape cover changes are demonstrated.

The assessment of potential drought events impacts on land use/cover dynamics is discussed by graphs and statistical analysis, in **Chapter 5**. Graphically the SPI drought index variations plotted among the percentage of changes in the areas covered by each one of the land use/land cover classes during the research period (1992-2003). Interpretation of each plot is carried out to highlight the typical processes viewed in the comparison charts. Furthermore, statistically, relationship between the SPI index as independent variable and the change in land use/land cover area as dependent variable are examined by a regression analysis.

All the research steps and the results down from the thesis are summarized in **Chapter 6**. In addition, in this chapter, author stated the merits and demerits of the thesis. However, at the end of this chapter, some recommendations are listed for the future investigations.

1.9 Chapter Summary

In summary, in this chapter, author, provides a general introduction on the main driving factors to land use/land cover alterations all over the world. First, drought as the most important factor is discussed from different points of view. Then, to underline the contrast between drought and aridity, author provides a general explanation by some related references. Next, the other key factors affecting natural landscape are discussed to clarify the role of human activities on land deformation in compare to natural phenomena such as droughts. After that, a general introductory description included in this chapter shows importance of satellite remotely sensed data in drought monitoring and multi-temporal land use/land cover mapping. Research problems are stated. Finally, followed by the objectives explanation, and defining the hypothesis and scope of the thesis.

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