Short Review of Climate and Land Use change Impact on Land Degradation in Tashkent Province

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Abstract

The paper is a short review about scientific articles, local reports and expert's opinion on land degradation caused by climate change (in particular temperature and precipitation change) and land use change in Central Asia (CA) with a special interest in Tashkent Province and aspects of regional water management in CA in order to clarify future study activities. Furthermore the paper presents the preliminary analysis of climate and land use changes in Tashkent Province and the author's opinion about the impact of these changes to potential land degradation. Climate change analysis based on the 0.5° resolution National Centers of Environmental Prediction (NCEP) Global Forecast System Reanalysis (CFSR) weather dataset of the 35 years period from 1979 to 2013 demonstrated the trend of increasing temperature and variable trend of precipitation, but small overall precipitation decrease in the croplands, pasturelands and grasslands of study area. Irrigated agricultural cropland increased to 7.800 ha from 1999 to 2010 in order meet population demand and increase national economy. Therefore, it is very importance to carry out comprehensive study of climate and land use change impacts on land degradation at regional scale using high resolution spatio-temporal remotely sensed data for better assessment of land degradation.

1. Introduction

Land degradation is the decline or loss of biological or economic productivity and complexity of different types of land covers such as irrigated croplands, rain-fed lands or rangelands, pasture, forest and woodlands in arid, semi-arid and dry sub-humid areas, resulting from land uses and human activities (§ 5, UNCCD 1994). The term land degradation originally comes from soil degradation and therefore it is often accepted the same like soil degradation because soil degradation negatively influence plant growth. Worldwide processes like global warming, land use land cover change, as well as population increase, advance and intensify land degradation. Particularly poor countries challenge degradation processes effect more than developed countries. Overuse of natural resources in environmentally sensitive areas also accelerates the process of degradation in these countries (Kertész, 2009). Land degradation has become a major problem in all CA countries and the issue needs urgent action because of rural population engagement in agriculture and livestock, moreover, global climate and land use changes in the region are threatening sustainable agricultural development and land management. The latest investigations showed the decrease of water resources during the last decades in CA and it is estimated to be continued according to future climate change scenarios. The CA countries depend on their rivers for drinking water, irrigation, and hydroelectric power. In Kyrgyzstan and Tajikistan as upstream countries the rivers are used mainly for hydro-power, while downstream, in Turkmenistan, Kazakhstan and Uzbekistan, the rivers are used for agricultural production in summertime. Agriculture is the largest water consumer in CA and a major employer of the CA's workforce. Agricultural sector delivers a large amount of each country's gross domestic product (GDP). Improving water quality in the environmentally degraded landscapes is an urgent need. CA's agricultural expansion and population growth over the past 30 years has placed a great strain on the area's water resources. Given the strong dependence of the CA's economies on irrigated agriculture, it was crucial to stabilize interstate water exchange immediately after independence. In October 1991 the newly independent countries signed an agreement "On cooperation in the Field of Joint Management and Conservation of Interstate water resources". This agreement affirmed the continuation of formerly existing Soviet structures of interstate water allocation. Transboundary sources of water make up the bulk of water resources useable to Uzbekistan and were used for irrigated agriculture whereas market economic principles have not been introduced to the agricultural sector in Uzbekistan (McKinney, 2004). Therefore Uzbekistan's government had to bring up substantial budget subsidies to stabilize maintenance of the huge water supply system. Regions under socio-hydrological stress are additional endangered by creeping land degradation. Therefore Uzbekistan and most of the CA countries have an urgent need of improved information systems for integrated water management under the thread of land degradation caused by climate and land use change. Geographic Information Systems (GIS) and remote sensing techniques play an important role and they have been used in many studies for detecting minor intensities and magnitudes of land degradation because of its low cost and time efficiency compared to field measurements. Considering above all, it is crucial to study the inter-relationships between climate, ecosystem, and land-use changes using remote sensing, field observations and modelling experiments for better understanding of changes (Lioubimtseva and Henebry, 2005). Land degradation can be mapped through assessing spatial-temporal dynamics of land-use and land-cover changes (Kessler and Stroosnijder 2006; Lu et al. 2007, cited in Dubovyk et al. 2013). Therefore GIS and Remote Sensing are effective tools to study land degradation at global, regional and local scales. Land degradation assessments based on remote sensing approaches are useful in developing countries, where reliable data and financial means are limited (Dubovyk et al., 2012). GIS and remote sensing based studies for the assessment and mapping of land degradation and desertification processes in arid and semi-arid regions are broadly recognized and well developed in a wide variety of research areas. Satellite technologies advancement together with remotely sensed image acquisition and analysis propose productive possibilities for monitoring land use and land cover change in aforementioned fields (Khiry, 2007).

2. Land Degradation in CA

More than 60% of the population lives in rural areas and work in the agriculture sector in CA. Land suitable for crop production is 20% of the total agricultural land and livestock production plays an important role in the region (NASA, 2014). Land degradation of desert and semi-desert rangelands all over the whole CA region has reached an alarming level, calling for immediate response (Nordblom et al., 1997). Many regional and international efforts have been done to understand the reasons, magnitude, rate and societal implications of land degradation, but these efforts have not been used effectively to address emerging issues. There are more than 16.4 million hectares of rangelands in CA, and its 73% are affected by degradation of various origins, including human induced and climate change impact. And it is estimated that human induced land degradation affect 7.4 million hectares (UNCCD, 2006). Overgrazing of livestock was the most serious type of degradation among all other types of degradation accounting for 44% in rangelands, followed by uprooting and cutting of vital shrubs for fuel (25%). Other degradation types, including all abiotic disturbances such as drought and wind erosion, accounted for only 30 % of total degradation (Yusupov, 2003). The study of changes in vegetation activity seasonally and annually at a regional scale in CA revealed an overall 11.35% increase and 35% of entire vegetated area of CA exhibited upward trends in growing season NDVI from 1982 to 2003. The study concludes that a strong climate impact on seasonal and growing season trends in vegetation activity in CA (Propastin et al., 2008). Net primary productivity (NPP) was derived in Kazakhstan during 2003-2011 by using Biosphere Energy Transfer Hydrology Model (BETHY/DLR) and results were studied regarding spatial, monthly, and inter-annual variations. The results showed mean NPP for Kazakhstan is 143 g C m^2 and it reaches its maximum productivity in June. Most monthly NPP anomalies occurred in northern semi-arid regions and these regions strongly affected by climate change. And also, arid ecosystems showed lower inter-annual NPP variability in comparison with semiarid ecosystems (Eisfelder et al., 2014). Shokparova and Issanova (2013) studied sierozem soils degradation in irrigated lands of the foothills of Ile Alatau near the Targap (Almaty/Kazakhstan) by measuring soil organic matter (SOM) content, texture and carbonate content parameters in the laboratory to determine changes between slope and plain areas. They found that soil humus content in 8° slopes is more than 1.17 times higher than in non-ploughed land covered with natural vegetation and in plain areas situation is same and more 2 times. Intensive land use in agriculture loses soil fertility and humus content in soil horizons. It is estimated that Uzbekistan annually losses US$ 31 million due to land degradation (World Bank, 2002 and Dubovyk et al., 2013). Soil degradation affects croplands and grassland of Fergana, Kashkadarya Bukhara and Navoi Provinces. Agricultural croplands of Andijan, Namangan, Tashkent and Surkhandarya Provinces strongly affected by water erosion.

About 33 % (161.000 ha) of the area of Khorezm Province area experienced different magnitude of land degradation because of low productive lands bordering on the natural sandy desert, proposing that low-fertility areas should be in top place in protection planning (Dubovyk et al., 2013). The number of cattle stock has increased by 46% and sheep and goats by 25 % since 1991. Poultry stock has been increasing more than two time starting since 1997 (Yusupov et al., 2010). Sheep farming operations are mainly based on the use of summer mountain pastures, and overgrazing has high contribution to land degradation. During the last two decades, there has been a large scale degradation of pasture lands, due to the unsustainable pasture management in livestock farming, poor pasture maintenance and other anthropogenic activities (Ibragimov et al., 2007). Rajabov and Thorsson (2009) studied vegetation changes in semi-desert rangeland of Uzbekistan caused by grazing using State and Transition model in order to detect grazing-induced vegetation patterns by NDVI derived from satellite imagery and he found considerable vegetation changes resulted to grazing in the study area. According to local expert's observations in the national report of Goskomzemgeodezkadastr (The State Committee of the Republic of Uzbekistan on Land Resources, Geodesy, Cartography and State Cadaster) irrigation and wind erosion, reducing soil humus content, rising ground water table and soil salinity were observed as an indicator of land degradation in Tashkent Province. Buka, Piskent, Parkent, Bustanlik, Akhangaran districts are influenced by irrigation erosion, and Bekobod district by wind erosion, while Akkurgan, Yangiyul, Bekabad districts are fronting soil humus content reduction. In some regions of the study area rising ground water table is increasing soil bulk density. Studying land degradation at field level in Tashkent Province at local level is extremely expensive and requires huge amount of labor work. Besides, investigating inter-annual changes in recent decades is impossible due to lack of field data.

3. Climate Change in CA

Climate aridity increases in CA because of higher temperatures and lower rainfall rates according to the future climates change scenarios. Future global warming may also reduce soil water content in many areas of semi-arid grassland in Asia. Heavy rainfall and increased wind speed due to climate change may increase soil water and wind erosion in some regions. Climate change accelerates the process of land degradation in semi-arid lands due to expansion of human population during the next decade (Sivakumar, 2007).

All above may create difficulties to agriculture and rural livelihoods in CA, but there is no detailed studies in this issue (Sommer et al., 2013). Climate plays an important role for vegetation condition and its development over the time. Much of the changes in photosynthetic activity by vegetation are being driven by climate change, especially global warming (Propastin, 2008). Comprehensive research in studying the interrelationships between climate, vegetation cover and land-use changes will help improve one's understanding of the role of CA's ecosystems in the global carbon cycle and global climate change. (Propastin, 2008). And also, climate change affects availability of water resources and these resources are not equally distributed in CA. Tajikistan and Kyrgyzstan are located at the upstream and Kazakhstan, Turkmenistan and Uzbekistan are downstream countries. Upstream countries have 80% of river runoff and consume only 16%, while the downstream countries contributed 14% of total river runoff and withdrew as much as 83% (Micklin 1988 and Chen et al., 2013). Many studies proved that glaciers in the Tien Shan and the Pamir continue to retreat and are shrinking. Most studies also confirmed the continuation of retreat and shrink, despite only few studies conducted on mass and volume changes (Unger-Shayesteh et al., 2013). In 2000-2001, 2008 and 2011 major crops yield failed due to the decrease of water supply, upstream water use and droughts in the last years (CACILM, 2006). Moreover, the amount of water is predicted to reduce further given the impacts of climate change and increasing demand from the continuously growing population (Lioubimtseva and Henebry, 2009, Perelet, 2007, cited in Dubovyk et al., 2013). CA countries will face temperature increase in the coming decades and aridity index is expected to increase throughout entire region, mostly in the western parts of Turkmenistan, Uzbekistan, and Kazakhstan. And precipitation is expected to decrease in Uzbekistan and Turkmenistan but medium increase is projected for winter in the eastern part of Kazakhstan and in Kyrgyzstan and Tajikistan. Temperature increase can benefit northern and eastern Kazakhstan by longer growing season, warmer winter and little precipitation increase; however western Turkmenistan and Uzbekistan can get affected from frequent droughts and extremely high demand to irrigation water (Lioubimtseva and Henebry, 2009). Arid zones of CA is verified to be sensitive to climate change in the last 100 years, it is expected to have negative influence by projected future temperature increase (IPCC: Climate Change, 2007 and Feng, 2013). Mountainous regions of CA is facing frequency of flood increase due to heavy rainfall and it is hardly affecting poorest population and modelled projections show even more changes in future. The temperature in CA may increase by 3.7°C on average by the end of this century, in particular during June, July and August which are more important months for agricultural crops and higher temperatures during vegetation period increase drought risk and decline productivity of agricultural production (IPCC, 2007 and Bobojonov and Aw-Hassan, 2014). Bobojonov and Aw-Hassan, (2014) studied climate change impact on agricultural producers in the far future by using bio-economic modeling. Modeling results showed that sensitivity of agricultural systems of CA to climate change depends on agro-ecological zones and socio-economic aspects. During 2010-2040 climate change will benefit farmers in Uzbekistan due to good weather conditions for crop growth, but it is expected to decline during 2070-2100 because of temperature increase and water deficit, especially if irrigation water declines. The impact of climate change on wheat productivity was studied in key agro-ecological zones of CA countries by using CropSyst model for 14 wheat varieties grown on 18 sites. The study found an increase in wheat yield by 12 % because of temperature increase which helped faster crop growth and high biomass accumulation in 14 sites but it varies between sites, soils, wheat varieties and agronomic management. Hotter temperature during flowering increases the risk of sterility and grain yield reduction in rainfed spring areas in the north and some parts of irrigated winter wheat in the south of CA (Sommer et al., 2013).

4. Climate Change Analysis in Tashkent Province

Tashkent Province (figure 1) is located in the northeastern part of the country, between the Syr Darya River and the western part of Tien Shan Mountains. It borders with Kyrgyzstan, Tajikstan, Sirdaryo and Namangan Provinces. Chatkal, Pskem, and Ugam mountain ranges are located on the northeastern and eastern parts of the Province (upper croplands and grasslands). There are three large water reservoirs located in the province: Charvak, Tashkent, and Akhangaran. Most of the area located in south and southwest is a predominant plain that slopes gradually towards the Syrdarya River (lower croplands and grasslands) (The Great Soviet Encyclopedia 1979). Total land area of Tashkent Province is 1.526 Mio. ha including 816.4 thousands ha agricultural land and 709.6 thousands ha of other land types (built-up, desert, forest and etc.). Agricultural lands are consisted 305.1 thousands ha of irrigated croplands, 425.4 thousands ha of pasturelands, 35.7 thousands ha of rainfed croplands, 38.5 thousands ha of gardens and 11.7 thousands ha of vineyards (Goskomzemgeodezcadastr, 2008). The population was 2696.1 thousand people in 2013 and population density was 194.6 people per km^2. The climate is a typically continental climate with humid, relatively mild wet winters and long, hot dry summers. Mean January temperature is -1°C to -2°C and the mean July temperature is 26.8°C. The average annual precipitation is 300 mm in the plain region, 300-400 mm in the piedmont region, and 500-600 mm in the mountains. Precipitation mostly occurs in the early spring and permanent snow cover is located in the higher mountains. The main river Syrdarya and its tributaries Chirchik and Akhangaron Rivers are fed by snow and glaciers and they are used for irrigation and hydroelectric power.

Climate change analysis was studied based on the data (Saha et al., 2014) of the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) from 1979 to 2013. CFSR weather data cannot replace the accurate weather data but it is useful where data are not available or existing data are not reliable due to random errors especially in developing countries. (Dile et al., 2014). Lack of reliable and precise data on climate and ecosystems required for regional climatic and biogeographic modelling is one of the major sources of uncertainty about vulnerability and impacts of climate and land-cover changes in arid lands of CA. (Lioubimtseva et al., 2005). Using CFSR precipitation and temperature data in watershed model provides better stream discharge simulations than using conventional weather data where stations are located more than 10 km from the watershed (Fuka et al., 2014) (Figure 2).

Based on the amount of precipitation, climate zone of Tashkent Province is divided into two regions: sub-humid and semi-arid. Precipitation exceeding 600 mm is sub-humid zone and precipitation in the range of 300-500 mm is semi-arid zone. Sub-humid zones are located in slope and in semi-arid zones are practiced by agriculture. Drought season lasts from June to August and during this period agricultural croplands and pasturelands receive less than 10 mm of precipitation. The results demonstrated the trend of increasing temperature and variable trend of precipitation, but little overall decrease over the croplands, pasturelands and grasslands of study area. The rainfall is not well distributed throughout the year, thus pastureland and rangelands of the study area are highly influenced by climate in drought seasons like 2000-2002 and 1995-1996.

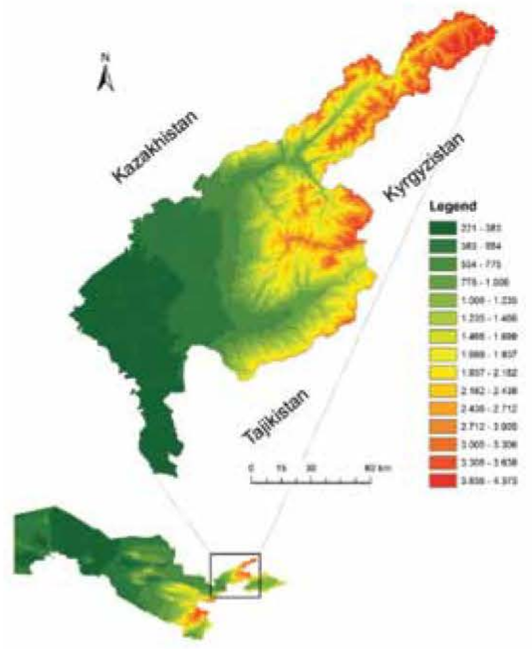

Figure 1: 30 m grid Digital Elevation Model (DEM) of Tashkent Province retrieved from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) (Tachikawa et al., 2011)

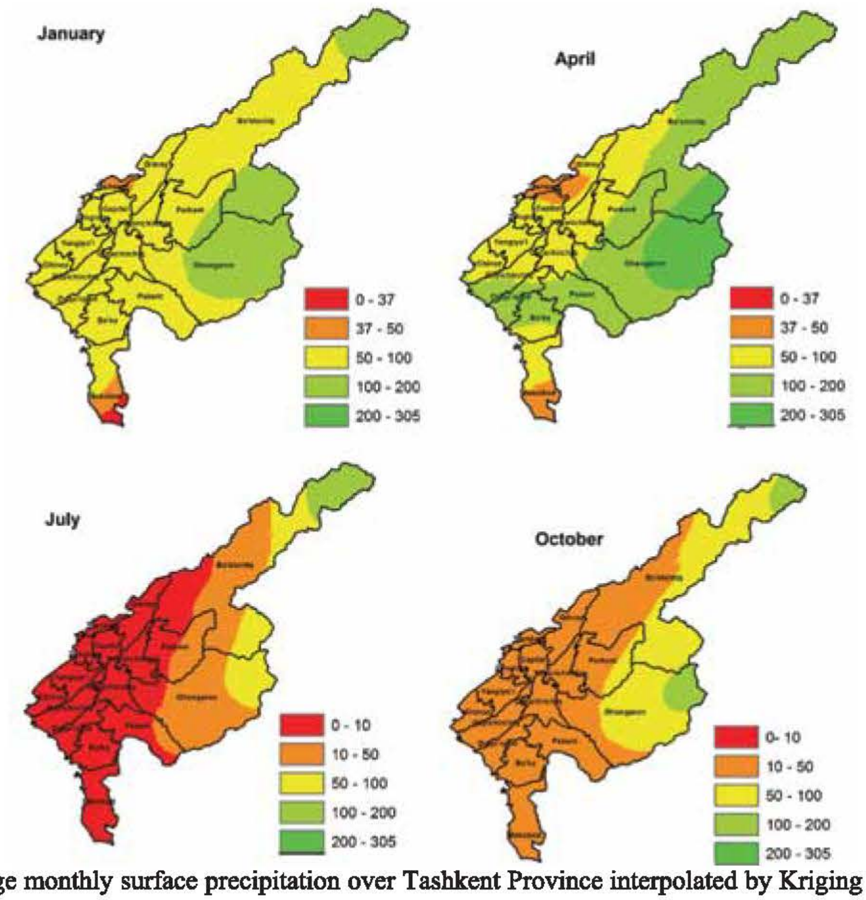

Figure 2: Average monthly surface precipitation over Tashkent Province interpolated by Kriging using CFSR weather data between 1979-2013

We may expect significantly decrease of evapotranspiration in arid and semi-arid climate areas due to lack of soil water content when temperature rises where precipitation is not expected to increase, and thus it accelerates the process of desertification. Some scientists believe that climate change (temperature and precipitation variability) can have advantage in the agricultural sector, because it can extend vegetation growing seasons, and higher concentration of carbon dioxide (CO_2) can improve plant growth. But agricultural land as well as pasturelands and grasslands in the entire study area dependent on irrigation and rain water respectively. In spite of the fact that in a global scale the temperature is increasing slowly and the precipitation is expected to be increased slightly but we should consider that the temperature increase and precipitation decrease is very active during the summer vegetation growing period in Tashkent Province. Therefore, it is crucial to study the impacts of climate change on land degradation during the vegetation period (Figures 3, 4, 5).

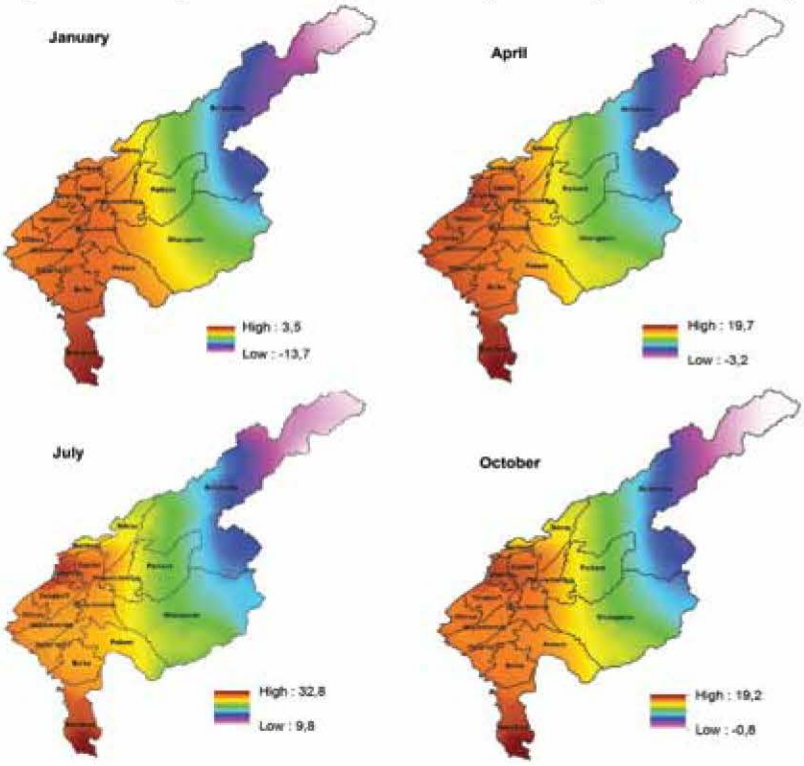

Figure 3: Average monthly surface temperature over Tashkent Province interpolated by Kriging using CFSR weather data from 1979 to 2013

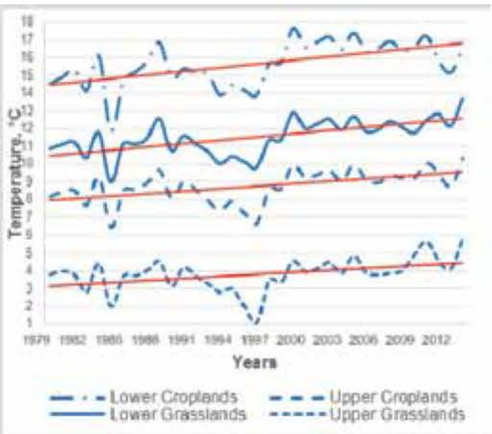

Figure 4. Annual average temperature change diagrams of croplands and grasslands in Tashkent Province

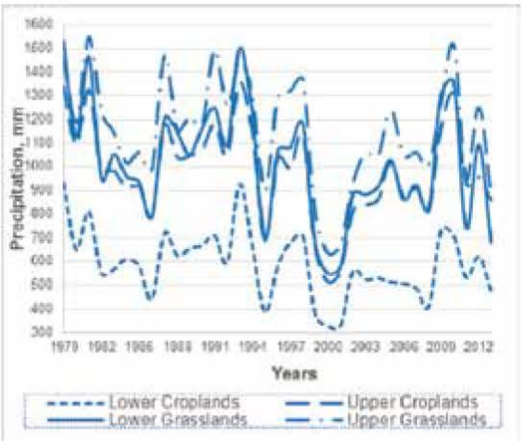

Figure 5: Annual precipitation change diagrams of croplands and grasslands in Tashkent Province

5. Land use changes in Central Asia

Studying changes in land use and land cover is a good indicator to study ecosystems vulnerability and landscapes to environmental change. (Peters and Lovejoy, 1992 cited in Sivakumar, 2007). Extreme agricultural practices in the last several decades are one of the important deriving causes of land degradation and it can be seen in many parts of the world and it is crucial to consider the influence of drylands climates on soil and vegetation, furthermore it is very important to adopt uniform criteria and method in order to assess desertification and monitoring of dryland degradation. And also, it is fact that extensive land use changes resulted in soil erosion of large areas in several parts of the world (Sivakumar, 2007). Irrigated land was expanded from 4.51 to 7.99 million ha from 1960 to 2000 in the Aral Basin in order to meet demands of increasing population and country development (Roll et al., 2005). Land cover and land use change analysis at regional scale in CA were carried out through classification approach with implemented classification tree model (C5.0) algorithm using MODIS time-series for the years 2001 and 2009. And the results showed significant changes in human induced water body's alterations, seasonal precipitation affect sparsely vegetation areas variability, forest loss by forest fires and logging (Klein et al., 2012). The other study of land-cover change and degradation in the CA deserts using remote sensing and geostatistic methods was done in three key time periods (mid-late 1970s, around 1990, and 2000). The study revealed degradation existed in some areas of the region because of enhanced oil recovery and another rangeland area is getting better due to decrease of livestock in Kazakhstan (Karnieli et al., 2008). Chen et al., (2013) studied land use land cover change and variations of ecosystem services which included net primary productivity (NPP), evapotranspiration (ET) and grain production in CA between 1990 and 2009 and they found most significant changes occurred in farmland abandonment and reclamation and farmland extent during 2000-2009. Farmland NPP was higher than natural vegetation and NPP increased with the rise of temperature in 2000 despite of decline in precipitation. The actual ET in the central area is lower than northern and eastern parts of CA. Besides, irrigated agricultural areas in one of the CA country Turkmenistan expanded to 86 % equivalent to a loss of about 4500 km^2 previously available for natural pastures since the 1980s. Pastures close to the irrigated and populated area were not affected and vegetation cover increase was found in many places of the country. But remote pastures were affected by higher degree of vegetation degradation, mainly because of the development of soil biogenic crust as well as flooding and technology related desertification occurred around man-made structures. (Kaplan et al., 2014). Irrigated lands in Uzbekistan increased from 2.2 million ha in 1953 to 4.21 million ha in 2013, thus the long-term growth rate was about 1.5 % a year. Expansion and densification of irrigated cropland in Kashkadarya Province of Uzbekistan was studied by classification trees method using Landsat MSS and TM data from 1972/73, 1977, 1987, 1998, and 2000. Cropland extent developed from 134.800 ha to 477.000 ha between 1972/73 and 2009 and winter wheat harvesting doubled to approximately 211.000 ha from 1987 to 1998 (Edlinger et al., 2012). Irrigated cropland in Tashkent province (figure 6) has grown up from 297.3 thousands ha to 305.1 thousands ha between 1999 and 2010 (Goskomzemgeodezkadastr, 2010).

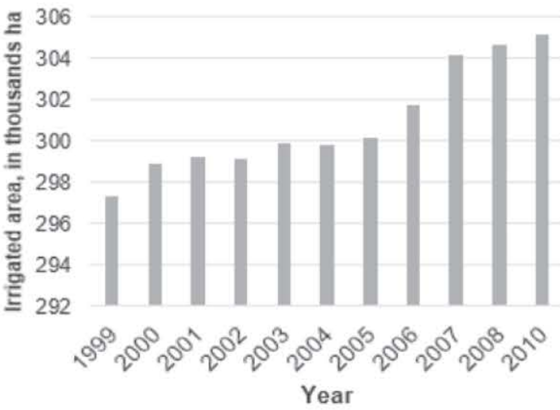

Figure 6: Changes in irrigated agricultural cropland between 1999 and 2010 in Tashkent Province

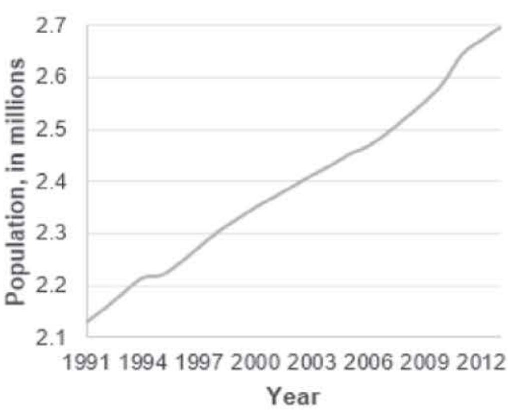

Figure 7: Population growth between 1991 and 2013 in Tashkent Province

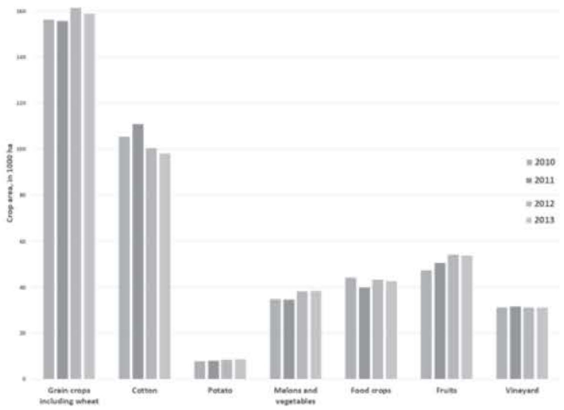

Figure 8: Changes in agricultural cropland area in Tashkent Province

According to the State Statistical Committee of Uzbekistan, it can be seen the increase of food crops together with fruits, potato, melons and vegetables while grain crops stay relatively stable and cotton areas slightly decreased between 2010 and 2013 (figure 8).

Population increase makes more pressure on natural resources and intensive land use practices which causes variety scale of land degradation in agricultural land as well as pasturelands and rangelands of Tashkent Province. Statistical data of the Province showed 20% population increase with 1.07 % average annual growth rate since 1991 (figure 7). The study area is consisted mostly by agricultural land, pasturelands and grasslands and they play an important role for rural population and national economy. Authors believe that each type of land use has its particular drivers of land degradation like agricultural land degradation by lack of soil water content, soil salinity, wind and water erosion, intensive land use, and pastureland as well as grasslands degradation by climate change, land use change, overgrazing and soil runoff.

6. Conclusions

Most of the carried out researches to study land degradation in CA countries used medium spatial resolution remotely sensed data such as NOAA/AVHRR and MODIS which pixels include mixture of many land covers but they do not capture certain land degradation. And throughout reviewing research articles as well as national and international reports, it is found that study related to land degradation caused by climate and land use changes at local level was not carried out throughout Tashkent Province in order to see the inter-annual spatio-temporal changes in land degradation caused by existing problems such as population increase, intensive agricultural practices and water availability in last decades. At the same time modeling the relationship between climate change, land use change and land degradation is very important for a better understanding of interrelationships between climate, vegetation cover, land degradation changes which helps to improve our understanding to find main drivers of land degradation in Tashkent Province. Climate change analysis showed increasing trend of temperature and highly variable trends in precipitation, but it indicated small overall decrease and the rainfall is not seasonally and quantitatively well distributed throughout the year, thus grasslands of the study area can be highly influenced by climate change in drought seasons. Furthermore, population increase is demanding more natural resources and expansion of irrigated croplands and this leads to intensive land use, overgrazing and other environmental problems in the study area. High resolution remote sensing data are useful for informing land management decisions and understand the interactions between land use change, climate change and land degradation where accurate field data of last decades are limited.

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