The use of Landsat Satellite Imagery in Mapping the Walnut Forest Area Changes

Seidrakmanova, S.,[1] Chymyrov, A.[1] and Choduraev, T.[2]
[1]N.Isanov Kyrgyz State University of Construction, Transport and Architecture, Kyrgyzstan
E-mail: saikal_seidrakmanova@mail.ru, akylbek2005@yahoo.com
[2]Ecology and Tourism Institute, I.Arabaev Kyrgyz State University, Kyrgyzstan
E-mail: choduraev.temirbek@mail.ru

Abstract
The main objective of this research is defining the walnut tree forests boundaries and other land use areas in the particular region of the country by using Landsat satellite imagery. Walnut forests occupy about 631 thousand hectares of the land they are the largest walnut forests on the planet. These forests are situated in the Arstanbap region, western Tien-Shan Mountains at the altitude from 1000m to 2200m. Besides walnut trees, there are other trees and shrubberies in these forests. This research is needed to investigate the actual forest change and environmental impact of the global warming as well as economical activities of the local communities. The importance of walnut forests of Kyrgyzstan is very high because of the ecological value of these relict walnut forests in the national and global level as natural world heritage. All forested areas in the country have environmental, hygienic, health and other protective functions according to the National Forest Code. The Physiological state of forests is largely determined by the content of chlorophyll and moisture level of the green fractions of vegetation. Currently, the walnut forests are experiencing a negative impact from agriculture, illegal logging and climate impact. Application of the multispectral and mutli-temporal series of Landsat imagery is one of the most efficient technologies for the long term environmental studies and analysis. This research has investigated the relative values obtained based on spectral indices as Normalized Difference Vegetation Index (NDVI), defined by the spectral reflection in the visible, near and mid-infrared spectral ranges. There are a number of changes in the walnut forest areas, identified within the research study.

1. Introduction

The rational use and protection of the natural resources, particularly the vegetation cover is one of the most important issues today. The analysis of global experience demonstrates the widespread use of remote sensing technology (both space and airborne), satellite navigation systems and Geographic information (GIS) technologies in the collection, processing and spatial analysis of the forest-related information. The Combination of remote sensing data and conventional ground-based methods has been the main method of the forest studies. Such integrated research and applied approach enables users to collect a large amount of relevant data and to create accurate and reliable thematic maps of the forested areas (Vogelmann et al., 2012). Integrated use of remote sensing imagery and GIS has been applied in this research work. The dynamics of the forest ecosystem can be monitored and controlled efficiently by using Landsat satellite imagery with the great advantage of its long-term and continuous operation since 1972, integrated and open datasets.

2. Landsat Satellite System in Forestry Monitoring

The Landsat series of satellites began with the launch of ERTS-1 (Earth Resources Technology Satellite, later renamed Landsat 1) in 1972 and it becomes the main remote sensing data to track urban growth, to monitor the effects of climate change, and to see deforestation affects on the global scale. The program has run continuously since 1972 providing scientists four decades of information in hand to track changes in land use over time with three primary satellite sensors evolving over thirty years: MSS (Multi-Spectral Scanner), TM (Thematic Mapper), and ETM+ (Enhanced Thematic Mapper Plus) (Figure 1).

As a joint initiative between the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), the Landsat Project and the data it collects support government, commercial, industrial, civilian, military, and educational communities worldwide. The multispectral imagery from the Landsat 8 satellite became available from May 30, 2013, and this mission continues the acquisition of high-quality data that meet scientific and operational requirements for observing global land use and land change. The Landsat-8 satellite captures entire Earth in every 16 days, in an 8-day offset from Landsat-7. Data collected by the instruments onboard the satellite are available to download at no charge from GloVis, EarthExplorer, or via the LandsatLook Viewer within 24 hours of reception. Landsat-8 carries two instruments: The Operational Land Imager (OLI) sensor includes refined heritage bands, along with three new bands: a deep blue band for coastal/aerosol studies, a shortwave infrared band for cirrus detection, and a Quality Assessment band.

The Thermal Infrared Sensor (TIRS) provides two thermal bands. These sensors both provide improved signal-to-noise (SNR) radiometric performance quantized over a 12-bit dynamic range. (This translates into 4096 potential gray levels in an image compared with only 256 gray levels in previous 8-bit instruments.) Improved signal to noise performance enables better characterization of land cover state and condition. Products are delivered as 16-bit images (USGS, 2016). On average, over 500 unique Landsat 8 scenes are acquired per day across the globe and sent to the USGS Earth Resources Observation and Science (EROS) Center for storage, archive, and processing.

Figure 1: Landsat satellites (USGS, 2016)

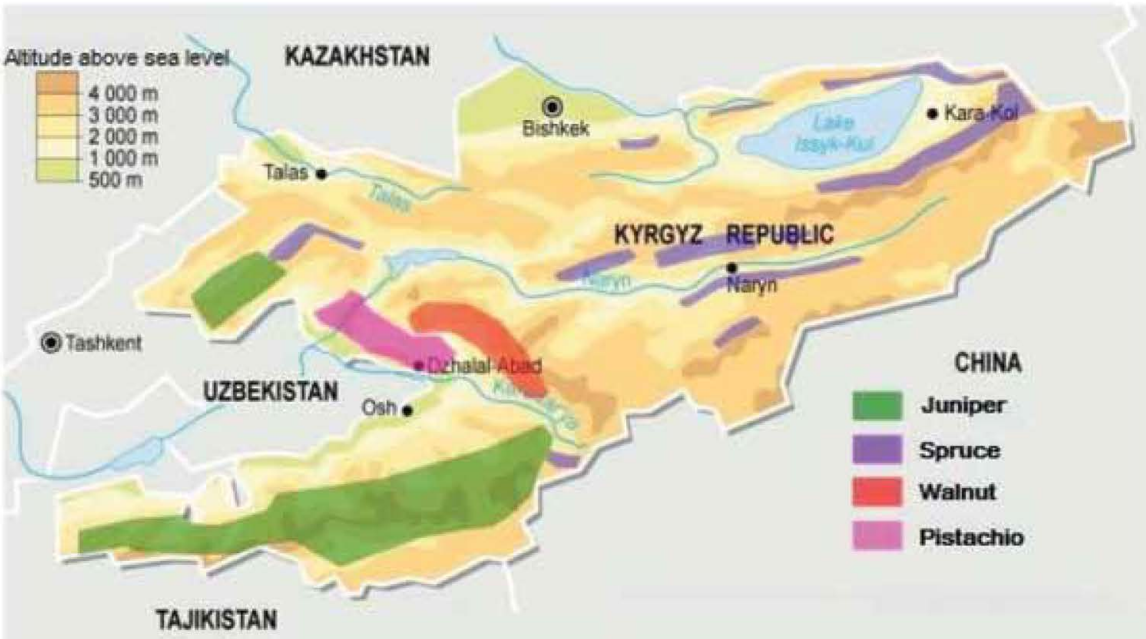

Figure 2: Main forest areas in Kyrgyzstan (JICA, 2016)

The geometrically corrected Level 1 products can be systematic terrain corrected (L1Gt) or precision terrain-corrected products (L1T). The highest available product derivative is made available for download over the Internet at no cost to users. A complete standard Level-1 product consists of 13 files, including OLI Bands 1-9 (one file per band), TIR Bands 10 & 11 (one file per band), a product-specific metadata file, and a QA file.

The literature review and preliminary study of using Landsat products in forestry (Roy et al., 2014, Sidorenko et al., 2015, Kurbanov et al., 2012 and Kostikova, 2016) have identified that Landsat images can be used efficiently in forest mapping, monitoring and management.

3. Walnut Forests in Kyrgyzstan

Kyrgyzstan has current forest cover about four percent of the total territory of the country or between 700,000 and 800,000 ha (Figure 2). All forests are state-owned and have been designated for biodiversity and nature conservation. They can be grouped into four main types (Müller and Venglovsky, 1998, Venglovsky, 1998 and Cornet and Rajapbaev, 2004):

- Spruce forests (Picea schrenkiana Fisch. et May.) occur in the west, in the center of the country and in the higher parts of the ranges north of the Fergana valley, mainly at altitudes between 1,700 and 3,000 m.a.s.l. Small areas of stands with the endemic Semenov fir (Abies semenovii B. Fedtsch.) can be found in the very west of the country.

- Walnut-fruit forests occupying the northern and north-eastern slopes of the Fergana valley. Under this term, a range of forest ecosystems dominated by fruit-bearing woody species is subsumed, including walnut (Juglans regia L.), apple (Malus spp.), hawthorn (Crataegus spp.), plumb (Prunus spp.), rose species (Rosa spp.) almond (Prunus amygdalus Stokes) and pistachio (Pistacia vera L.). Forest stands of walnut and its accompanying species grow in the valleys and hills in altitudes between 800 and 2,400 m.a.s.l., whereas pistachio forests and almond stands grow in the dryer, lower parts of the hills. The walnut-fruit forests of Kyrgyzstan are considered to be the biggest remaining areas of this particular forest type worldwide and therefore to be of global significance for biodiversity conservation.

- Juniper forests (Juniperus spp.) grow under arid conditions or in very high altitudes up to 3,500 m.a.s.l. in the very south of the country and dispersed over the country. These forests are typically open stands, formed by a tree and crawling forms of Juniper.

Currently, the state of the country's forests is deteriorating. This is mainly due to increased pressure on forests on the one hand and the breakdown of an effective forest management system after independence, on the other. The state is unable to assure effective forest management on its own as a result of a lack of funding for protective and maintenance activities. At the same time, pressure on easily accessible forests by a variety of stakeholders has increased, since the economic changes have resulted both in difficulties in obtaining energy supplies other than fuelwood and in reduced opportunities for salaried employment and therefore in a relapse into subsistence agriculture in all parts of the country (Fisher et al., 2016).

Walnut forest (mainly Juglans Regia) of southwest Kyrgyzstan has grown in the mountains surrounding the eastern margin of Fergana Valley (Figure 3). As a large rare climax walnut forest as anywhere in the world, its proper protection and management are one of the major challenges for the forest authorities of Kyrgyzstan because of attracting by many researchers and experts. The forests in this region are not only wild grows walnut but many fruit varieties such as apple and plum; the forests also have very high productivity and economy. In addition, the pistachio and almond forests also exist in the low-altitude region as dry area (JICA, 2016).

The State Forest Service (SFS) is the responsible state body for the implementation of the national forest policy, for forest management, hunting, management of national parks and other protected areas and for biodiversity conservation. It is part of the presidential administration and has its headquarters in the capital Bishkek. Provincial forest administration units are in charge of forest management at the level of each province (oblast). Locally, more than forty State Forest Farms (leshoz) are responsible for the protection and management of the forests and of state-owned non-forested land located on leshoz territory, mainly pastures but sometimes also arable land. The entirety of the forested and non-forested land on leshozes forms the state forest estate (Goslesfund) all of which is destined for forestry use in the long run.

The walnut forest of leshoz "Arstanbap-Ata" is selected for this study. The territory of leshoz is situated between the Fergana and Chatkal Mountains of the Tyan-Shan range. The largest on

Earth Arstanbap walnut forest area is located above 1,200 meters in the territory of the Bazar-Korgon rayon, Jalal-Abad oblast of Kyrgyzstan. The forest area of the leshoz territory was mapped on scale 1:10000 in 1975 with total 32748 Ha. This area was estimated 28279 Ha in 1989 and has 16297 Ha today. The forested area is reduced because of the land use and administration border changes, which are still under discussions.

There are 4 settlements in the territory of leshoz "Arstanbap-Ata" – Gunkhana, Arstanbap, Belterek and Dashman.

It is estimated that more than 100,000 people live in villages within or at the periphery of the forest belt. Agroforestry resource use is predominant in these forests, which can be described as a cultural landscape, a mosaic of natural, often strongly anthropogenically influenced forest stands, forest plantations, farming plots in forest openings and increasingly in open forest stands, and pastures. Some people actually farm on plots within leshoz territories and, although illegal, grazing in leshoz territory is very much the norm and is an important activity in forested areas (Fisher et al., 2016).

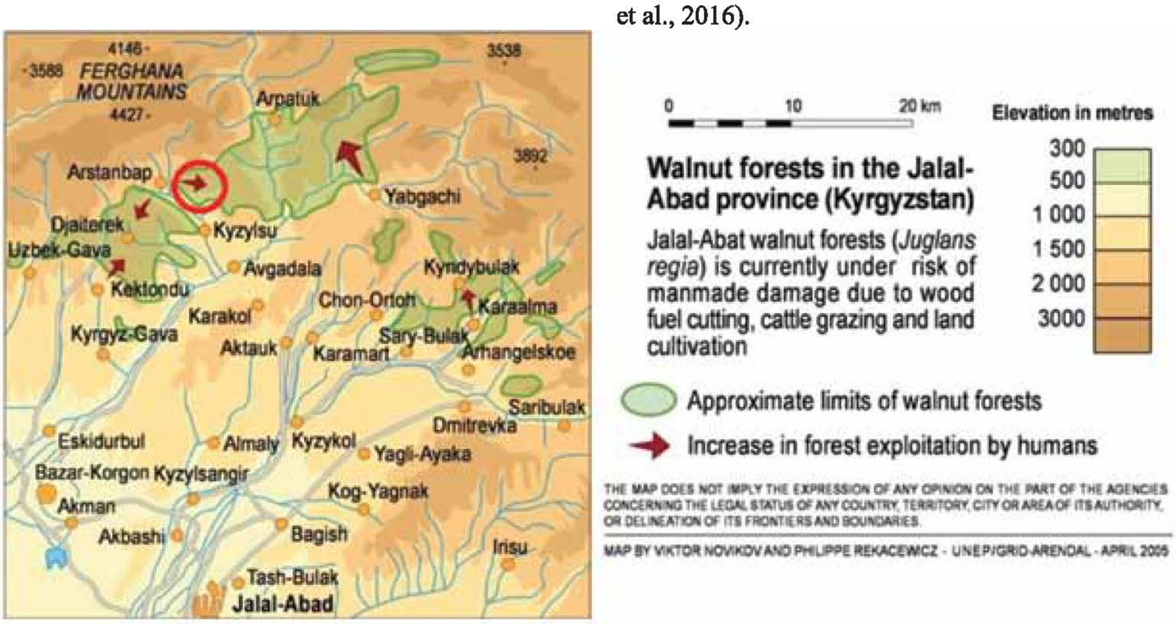

Figure 3: Walnut forest areas in the Jalal-Abad oblast (study area location is in the red circle)

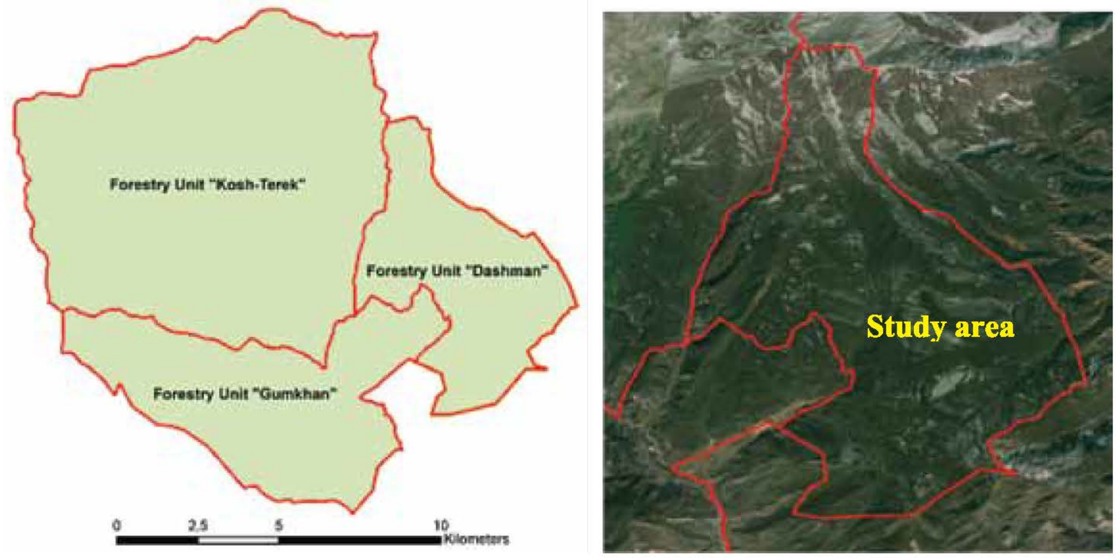

Figure 4: State Forest Farm (leshoz) "Arstanbap-Ata": a) map of forestry units; b) forestry unit "Dashman"

4. Data collection and processing

The leshoz "Arstanbap-Ata" is divided into three forestry units - lesnichestvo: Gumkhan, Dashman and Kosh-Terek. Paper maps of these forestry units were georeferenced and digitized using ArcGIS 10.2 software (Figure 4). These digital layers of unit borders were used for the data collection, processing and analysis using GIS software and online cartographic services as Google Earth, SAS Planet, and USGS Earth Explorer etc.

Landsat products were searched and downloaded from the U.S. Geological Survey website (http://earthexplorer.usgs.gov) using online tools and digital maps of the study area. Analysis of the available remote sensing imagery has identified the most suitable period in August and the lesnichestvo "Dashman" with largest walnut forest area for the further detailed study (Figure 5).

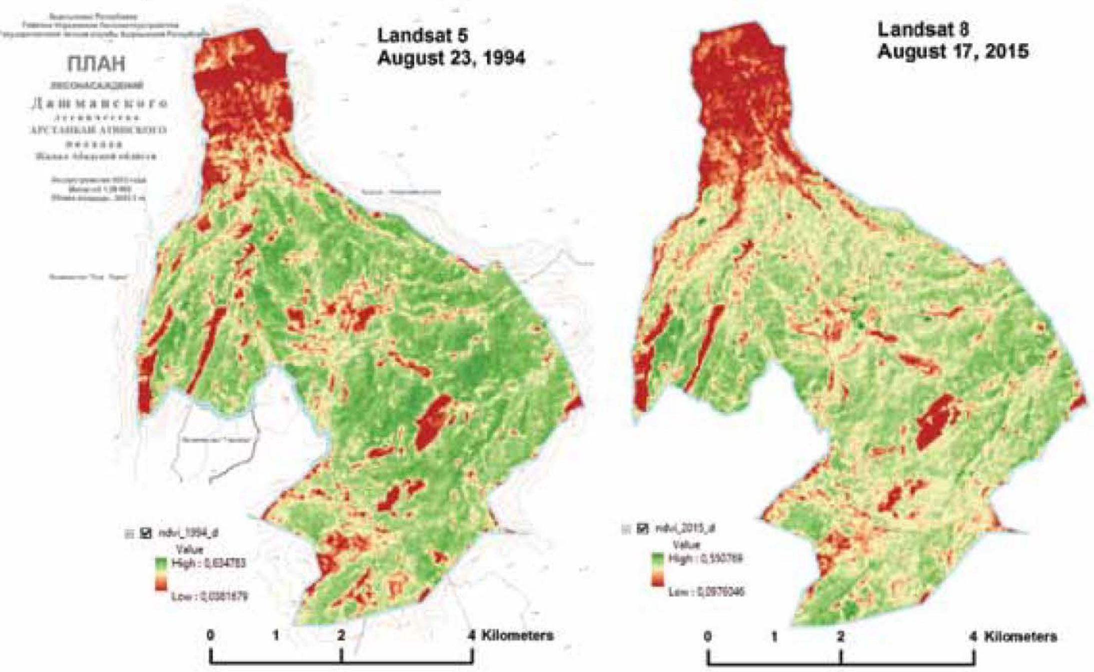

Figure 5: NDVI values for different sensors

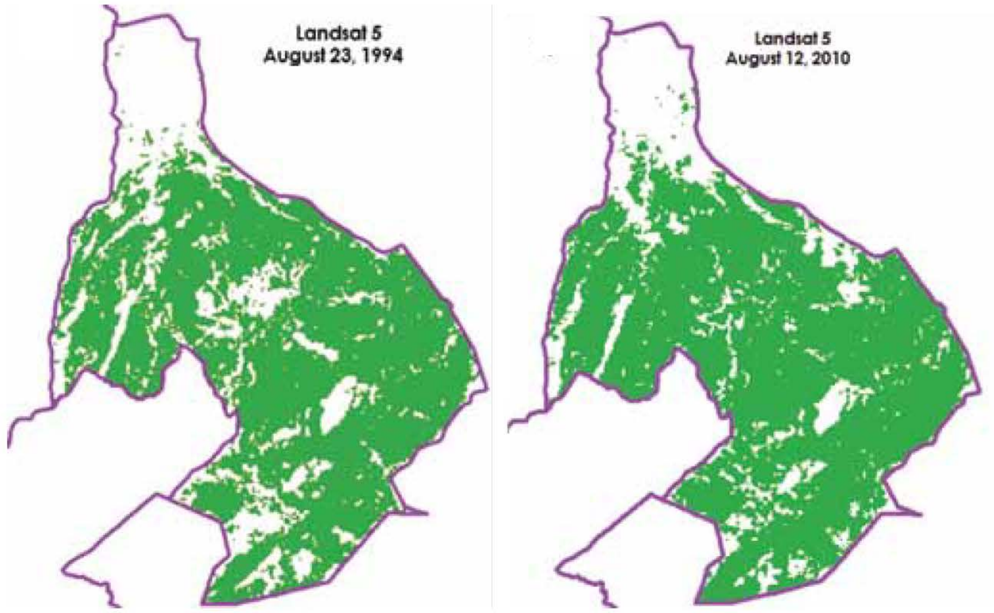

Figure 6: The changes of walnut forest areas in different years

Four Landsat images with best quality were selected and downloaded from the USGS Data Archive for the further processing and analysis:

- LM21630311975228AAA04 (Landsat-2, August 16, 1975);
- LT51520311994235ISP00 (Landsat-5, August 23, 1994);
- LE 71520312001214SGS00 (Landsat-7, August 2, 2001);
- LT51510312010224KHC00 (Landsat-5, August 12, 2010);
- LC81520312015229LGN00 (Landsat-8, August 17, 2015).

Normalized Difference Vegetation Index (NDVI) - the numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. NDVI has been used to estimate vegetation health, crop yields, pasture conditions and rangeland carrying capacities among others. It is often directly related to other ground parameters such as percent of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. NDVI information can be derived using the satellite bands that are most sensitive to vegetation information (near-infrared and red). The bigger the difference therefore between the near-infrared and the red reflectance, the more vegetation will be on the land surface.

The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands:

$$NDVI= (NIR-RED) / (NIR+RED)$$

Equation 1

This formulation allows us to cope with the fact that two identical patches of vegetation could have different values if one were, for example in bright sunshine, and another under a cloudy sky. The bright pixels would all have larger values, and therefore a larger absolute difference between the bands. This is avoided by dividing by the sum of the reflectance values. Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice, extreme negative values represent water, values around zero represent bare soil and values over 0.6 represent dense green vegetation (Figure 5).

Use of different Landsat sensor types and dates have created several issues as spatial, spectral and temporal resolutions.

Different values of NDVI for different sensors were determined by using expert assessments, past studies and field investigations. The results of the research study are given in the Figure 6 as different forest areas identified in different time periods using Landsat images with different spectral parameters of the vegetation reflectance. Different sensors of Landsat satellites have different NDVI values for vegetation cover. Landsat-2 bands have NDVI>0.33 for identification of walnut forest areas with 90 m resolution. Landsat-5 has NDVI>0.44 (Figure 6) with and Landsat-7 with NDVI>0.39 can be used to classify the walnut trees with other vegetation types. The latest walnut area classification can be realized using Landsat-8 imagery with NDVI value 0.34 for the further field verification.

5. Conclusion

The preliminary analysis shows ongoing positive growth in the walnut forest areas and possibility of using Landsat images in mapping and monitoring such land cover dynamics. Different Landsat sensors have different bands, combinations and NDVI values, which need further investigations for the detailed spectral, temporal, spatial resolutions and other properties of the walnut trees. These results will be integrated into the new forest geodatabase and walnut forest researches.

References

Cornet, J. G. and Rajapbaev, M., 2004, Criteria and Indicators for Sustainable Management of Juniper Forests in Southern-Kyrgyzstan. Nancy, Laboratoire de Politique Forestière de l'Ecole Nationale du Génie Rurale, des Eaux et des Forêts. *Commission of the European Communities*. 96.

Fisher, R. J., KSchmidt, K., Steenhof, B. and Akenshaev, N., 2016, Poverty and Forestry - A Case Study of Kyrgyzstan with Reference to Other Countries in West and Central Asia. *Food and Agriculture Organization of the United Nations*. http://www.fao.org/docrep/007/j2603e-/j2603e00.HTM

Japan International Cooperation agency (JICA), 2016, Project for the Support for Joint Forest Management in the Kyrgyz Republic. http://jicajfm.aknet.kg/index.php?act=view_cat&id=5

Kostikova, A., 2016, Interpretation of band combinations of Landsat TM / ETM+. http://gis-lab.info/qa/landsat-bandcomb.html. 2016

Kurbanov, E. A., Vorobiev, O. N., Gubaev, A. V., Lezhnin, S. A. and Demisheva, E. N., 2012, Four Decades of Forest Research with the use of Landsat Images. Vestnik of Volga State University of Technology. Ser.: Forest. Ecology. *Nature Management*. Issue 1(21), 18-32.

Müller, U. and Venglovsky, B. I., 1998, L'économie des forêts de montagne dans l'Ex-URSS: l'exemple du Kirghizistan. Revue Forestière Française Numéro Spécial. 148 - 160.

Roy, D. P., Wulder, M. A., Loveland, T. R., Woodcock, C. E., Allen, R. G., Anderson, M. C., Helder, D., Irons, J. R., Johnson, D. M., Kennedy, R., Scambos, T. A., Schaaf, C. B., Schott, J. R., Sheng, Y., Vermote, E. F., Belward, A. S., Bindschadler, R., Cohen, W. B., Gao, F., Hipple, J. D., Hostert, P., Huntington, J., Justice, C. O., Kilic, A., Kovalskyy, V., Lee, Z. P., Lymburner, L., Masek, J. G., McCorkel, J., Shuai, Y., Trezza, R., Vogelmann, J., Wynne, R. H. and Zhu, Z., 2014, Landsat-8: Science and Product Vision for Terrestrial Global change Research. *Remote Sensing of Environment*. Vol. 145, No. 5, 154–172.

Sidorenko, V. M., Doroshenkova, E. V., Zhafyarov, A. V. and Ilyin, F. S., 2014, Assessment of Different Types of Forest Cutting Based on Landsat 8 Satellite Imagery. *Lesotechnic Journal*. Issue 1 (17), Vol. 5, 97-109.

Venglovsky, B. I., 1998, Potential and Constraints for the Development of the Walnut-Fruit Forests of Kyrgyzstan. Biodiversity and Sustainable use of Kyrgyzstan's Walnut-Fruit Forests. J. Blaser, J. Carter and D. A. Gilmour. Gland, Cambridge and Bern, *IUCN and Intercooperation*. 73-76.

Vogelmann, J. E., Xian, G., Homer. C. and Tolk, B., 2012, Monitoring Gradual Ecosystem change using Landsat Time Series Analyses: Case Studies in Selected Forest and Rangeland Ecosystems. *Remote Sensing of Environment*. 122. 92–105.

US Geological Survey (USGS) and NASA, 2016, Landsat 8. http://landsat.usgs.gov/landsat8.php, accessed on February 2.