VERSITA

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Int. Agrophys., 2012, 26, 249-257
doi: 10.2478/v10247-012-0037-3

Landsat thermal band efficiency on characterizing mulched soil surface

M.M. Hashemimanesh[1]*, *H.R. Matinfar*[2], *S.K.Alavipanah*[3], *and G.Zehtabian*[1]

[1]Department of Agriculture and Natural Resources, University of Tehran, Karaj, Iran,
[2]Department of Soil Science Engineering, Lorestan University, Khoramabad, Iran
[3]Department of Cartography, University of Tehran, Tehran

Received January 24, 2011; accepted Februry 8, 2011

A b s t r a c t. In order to study petroleum mulch effects on soil, and sand dune fixation, thermal, and reflective bands of Landsat thematic mapper TM and ETM data, and other sources of information including topographic maps, aerial photos, and field work were used. The methodology was comprised of: images processing, statistic analysis, and relationship between thermal and reflective data. The results from image processing show that the behaviour of the Landsat thermal data is completely different from reflective data. The results from colour composite images including thermal bands have shown the capability of thermal bands in reparability of mulched and non-mulched areas. It was generally concluded that selection of TM, ETM thermal band is an important step to evaluate the area covered with petroleum mulch. Ratio mulch index was introduced as a best band combination in order to imagine mulch decomposition.

K e y w o r d s: petroleum mulch, sand dune, erosion, ratio mulch index, thermal band

INTRODUCTION

Active and mobile sand dune usually located in hard climatic condition of Iran, and therefore it is too difficult to study petroleum mulch effects on sand dune fixation, temperature change, and plant growth. Remotely sensed data might be a useful tool to overcome some of these problems. Because remotely sensed data, firstly can overcome the ability to differentiate mulch/ non-mulch, and other land cover types, secondly, remotely sensed data can provide a synoptic view of area. Mulch is simply a protective layer of a material that is spread on top of the soil. Mulches can either be organic, such as grass clippings, straw, gravel, bark chips, and similar materials or inorganic, such as stones, brick chips, petroleum and plastic. Both organic and inorganic mulches have numerous benefits. It can reduce run-off throughout the year, reduce evaporative losses and can increase infiltration and can also increase the stability of the surface soil through increased organic matter content and increased biological activity (Czyż and Dexter, 2009; Josa *et al.*, 2010).

Water deficit in plants may lead to physiological disorders, such as a reduction in photosynthesis and transpiration. The mulching technique is known to reduce evaporation. A strong long-term saving effect has been shown by comparing soil samples taken from mulched and bare fields throughout the year (Oyedele and Tijani, 2010; Said-Al Ah and Abdou, 2009; Tejedor Salguero *et al.*, 2003).

In addition to the water conserving effect of mulching, it may also dampen soil borne disease; eliminate weeds; keeps the soil from overheating; increase the infiltration; supplies nutrients; promotes living organism populations in soil; lessens the irrigation intervals; and increases soil aeration by preventing soil compaction *etc*. (Dahiya *et al*., 2007; Diaz *et al*., 2005; Yamarak *et al*., 2004). Further that large porous composition increased throughout the soil surface, provides more water to turn into soil moisture and decreases storm water runoff (Mulumba *et al*., 2008). Dahiya *et al*. (2007) reported that untreated harvest residue (stem and straw) reduced the water loss 0.39 mm at average per day, compared to control plots, in typical Hapludalf powdery wet clay in Germany. Besides, mulching also decreased soil temperature 0.74 and 0.66°C at depths of 5 and 15 cm, respectively. Using plastic mulching materials may result in unexpected consequences. For example, soil temperature in a field mulched with plastic materials may go up to 8-10°C higher than that of a field mulched with organic materials during summer (Brady and Weil, 1999).

*Corresponding author's e-mail: Mirmusa@yahoo.com

Sand dune stabilizing projects and anti-desertification programmers, initiated in 1965, annually cover about one million hectares of degraded land. Goal of this project were to stabilize sand dunes include reforestation programmers, the construction of wind-breaks, and the application of mulch. Until now, more than three million hectares of degraded lands have been reclaimed. Determining the status of mulched regions is problematic and costly by traditional procedures. Data of remote sensing may be a useful tool to solve the problem in desert. Since every year several studies were made in the case of desertification by using satellite data in local and global area (Eklundh and Olsson, 2003; Geerken and Ilaiwi, 2004; Herman *et al*., 2005; Hostertet *et al*., 2003; Petit *et al*., 2001; Röder *et al*., 2007; 2008).

Soils in arid regions differ widely in their spectral response. This depends on soil colour, mineralogy, textures, presence of sand and rocks, surface roughness and various other factors. Recent research has suggested that reflectance in certain spectral bands have been correlated with soil properties and could provide inexpensive predictions of soil physical, chemical and biological properties (Daniel *et al*., 2004; Dunn *et al*., 2002; Roy *et al*., 2006; Stamatiadis *et al*., 2005).

The objective of this study was to introduce a best band combination for clarifying petroleum mulch on sand dunes in desert area of Iran using thermal and reflective bands of Landsat thematic mapper TM and ETM data.

MATERIALS AND METHODS

The Khuzestan province is SW part of Iran (29°57’-33°00’N, 47°40’-50°33’E) (Fig. 1). The study site covers an area of approximately 50 000 ha. Because of subtropical high pressure cloud could not compose and raining hardly happens there. Mean annual precipitation is approximately 234 mm, falling predominantly during winter. Mean annual evaporation is 2 178 mm. Average temperature is 24°C. The most of the area is covered with sand dune. In this study, remotely sensed data from TM, and ETM+ bands dated, August 1991 and August 2002, respectively, the topographic maps (1: 25 000) and fieldwork have been used for multitemporal analysis. The software such as ILWIS 3, ARC VIEW 3.1a, ENVI 4, 2, were used.

The study was conducted in the north of Khuzestan desert because it contains petroleum mulches, decomposed mulch, vegetation cover and biological crusts typical of that found throughout the desert. The appearance of the study area is shown in (Fig. 2). The field studies were done in mulched areas from August 20th to 30th 2002. The mulching process was made after rainfall to keep moisture for growth of cultured seedlings. This region has been covered with petroleum mulch by 2-5 cm diameter (Fig. 2a). In regions with old mulching, mulches has been decomposed and incorporated with soil and changing in colour of soil (Fig. 2b).

After mulching, planting causes vegetation canopy and biological fixation. Seedling of shrubs and trees were planted in mulched areas that shrubs consist of *Panicum divisum, Cornulaca leucacanta, Penisitum divisum, Capparis spinosa, Carthamus oxycantha, Imperata cylindrical, Prosopis stephaniana*, *etc*. and trees are *Prosopis juliflora, Popolus euphractia, Aucalyptus cameldulensis, Callygonum comosum, Lycium shawii, Crotalus procera, Tamarix pallasi, Ziziphus spina-christi, Acasia Victoria*, *etc*. In some areas with little canopy or growing of seedling, weed species were observed after sand dunes fixation that created biological crust in desert (Fig. 2c). Last area (Fig. 2d) was sand dunes that mulching has not been made and there were no canopy in this area.

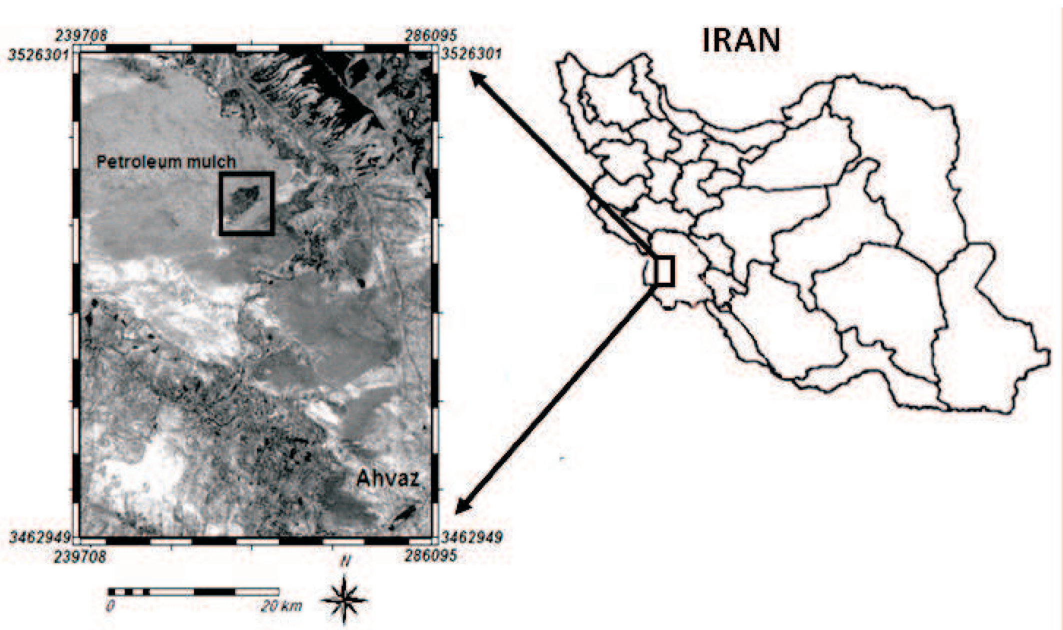

Fig. 1. Location of study area in Khuzestan province, Iran.

Geo-referencing registered the image into Universal Transverse Mercator (UTM) coordinates; using 1: 25 000 scale topographical maps of the study area, thus allowing cross-referencing of images across space and time. Root mean square (RMS) error of <0.5 pixels was recorded, indicating a high degree of accuracy. Dark object subtraction (DOS) in perhaps simplest yet most widely used image-based absolute atmospheric correction approach for classification and change detection applications (Cheng and Lei, 2001). In this study the lowest digital numbers were assumed to represent the values contributed by up welled radiances and were subtracted from the original digital values of the satellite images. The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features. Contrast stretching was applied on the two images and false colour composites (FCC), principal component analysis (PCA) and band ratio were produced.

After pre-processing images, correlation matrix between all bands was evaluated (Table 1). Then spectral average of phenomena in the study area including sand dunes, petroleum mulch, decomposed mulch, biological soil crust was compared with each others. After spraying on soil surface, petroleum mulch is gradually decomposed while affecting appearance and physicochemical properties of soil. Hence, the soil properties of areas under study were scheduled and studies according to the soil line. Then, in order to evaluate the capacity of band combination in phenomena clarification, a variety of false colour composite (FCC) was provided.

Petroleum mulch is black, and the rate of heat absorption and its distribution to its surroundings is high and leads to heat increase in soil and its surroundings. Thus, it is expected that the behaviour of this phenomena in thermal band to be different from visible bands. Regarding this hypothesis, the

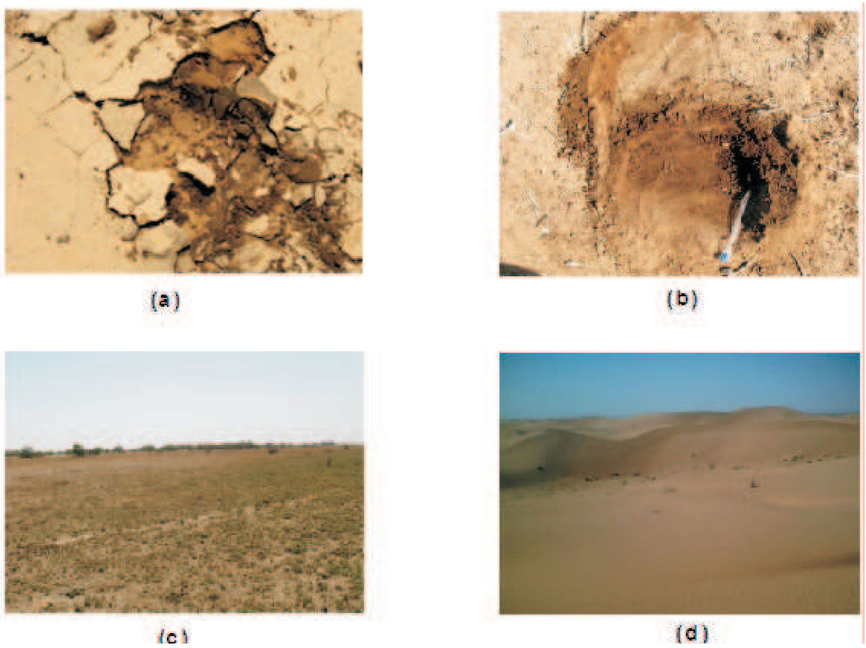

Fig. 2. Different futures in field study: a – petroleum mulch on soil surface, b – decmposed mulches, c – biological crusts, d – sand dunes.

T a b l e 1. Correlation matrix between TM bands

TM	Band1	Band2	Band3	Band4	Band5	Band6	Band7
Band 1	1.00						
Band2	1.00	1.00					
Band3	0.98	0.99	1.00				
Band4	1.00	1.00	0.99	1.00			
Band5	0.98	0.98	0.99	0.99	1.00		
Band6	0.90	0.91	0.93	0.91	0.93	1.00	
Band7	0.99	1.00	0.99	1.00	0.99	0.92	1.00

operations of image clarification with the aim of observing the effects of petroleum mulch were carried out by algebraic calculation. Ratios may also provide unique information not available in any single band that is useful for discriminate between soils and vegetation (Jensen, 1996). Different band combinations between visible and thermal bands by band ratio operation were formed (Table 2). Images resulting from band ratio were compared with information of mulching procedure and field observations.

For determining the best band ratio for petroleum mulch clarification, Spectral reflectance of petroleum mulch were evaluated in all bands of TM and ETM sensors, then (TM6-TM)/(TM6+TM2) as the best band combination was selected. To study the capacity of this band ratio in petroleum mulch clarification, this combination was compared with the bare soil index (BSI). Remote sensing of arid regions is difficult and needs innovative techniques (Ray, 1995). Finally, this band combination was introduced as a suitable index for petroleum mulch clarification in desert area of Iran (Fig. 3):

Ratio mulch index (RMI) = (TM6-TM)/(TM6+TM2).

T a b l e 2. Band ratio composed with TM thermal and visible bands

Band ratio	
TM6/TM1	(TM6-TM1)/(TM6+TM2)
TM6/TM2	(TM6-TM2)/(TM6+TM2)
TM6/TM3	(TM6-TM3)/(TM6+TM3)
TM6/TM4	(TM6-TM4)/(TM6+TM4)
TM6/TM5	(TM6-TM5)/(TM6+TM5)
TM6/TM7	(TM6-TM4)/(TM6+TM7)

RESULTS AND DISCUSSION

Results of correlation matrix showed that thermal band has low correlation with visible bands. Dark petroleum mulch by not only absorbs a high amount of heat, but also causes increase in the heat of soil by distribution to the surroundings indicating the high amount of reflection of petroleum mulch in thermal band. Investigation of distribution of soil pixels in soil line procedure showed that, the soil of desert area are scattered in three points around the soil line (Fig. 4). Region (a) relates to the areas with sand dune that have high reflex compared to the others. Petroleum mulch is mixed with sand dunes after decomposition, and affects physico-chemical properties of soil. In addition, it fixes sand dunes and form biological crust on them (Region (b)). Region (c) shows mulched area. Petroleum mulch has low spectral reflex due to its dark colour, and in terms of properties is similar to dark, humid soils and is located near the source of soil line as showed.

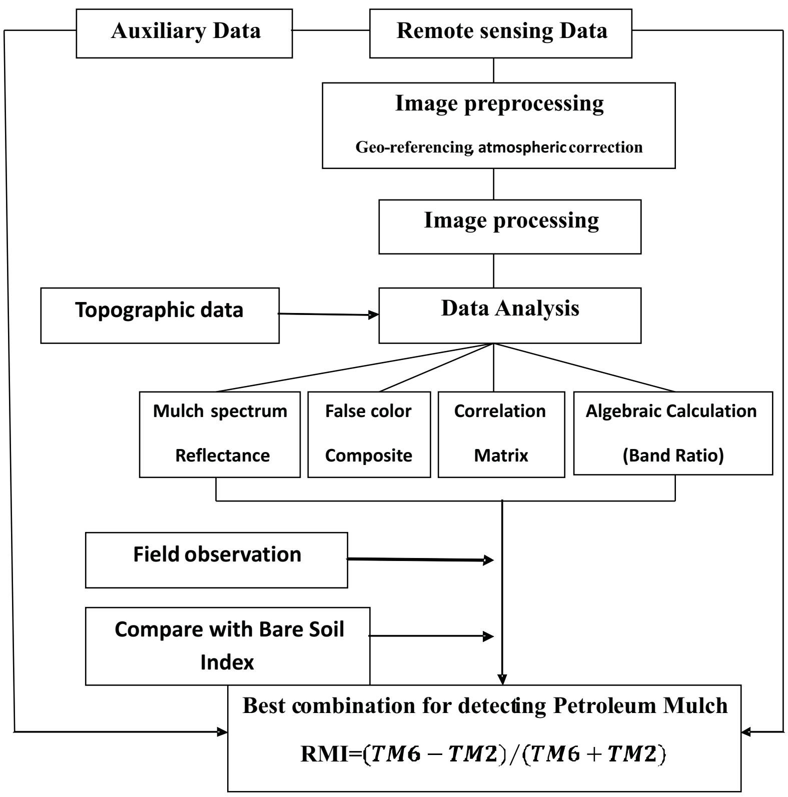

Fig. 3. Process flow-chart clarifying petroleum mulch in desert area of Iran.

Results showed that, the spectral averages of existing phenomena in the area have almost similar trend but are different in reflex intensity (Fig. 5). Difference between sand dune spectral reflectance and petroleum mulch spectral reflectance shows that vegetative covering on the sand dune has formed an area with completely different properties compared with its former condition, in a way that in all reflectance bands, the reflex of sand dunes is higher than that of mulched areas. But in TIR (thermal infrared) band, the spectral reflectance of petroleum mulch areas is more than other phenomena which is a result of the absorption of environmental temperature and its distribution. False colour composite images have clearly distinguished mulched areas from others (Fig. 6). In False colour composite image (FCC 643) TM sensor 1991, mulched area has clearly been distinguished with red colour. Moreover, in false colour composite image (FCC 643) ETM sensor, mulched area has distinguished with red colour too. Comparison between these two images shows that not only mulched area is clearly distinguished in these images, but also the process of mulching in desert area could be understood. In addition, the areas mulched in 1991 with a high concentration in TM sensor have a lower concentration after some years with decomposing mulch (Fig. 6a, b).

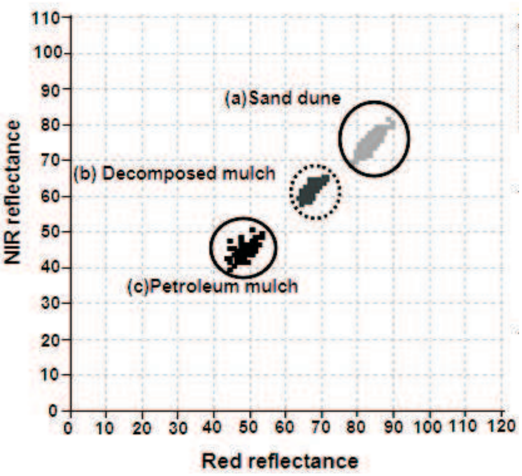

Fig. 4. Spectrum reflectance of soil samples in sudy area.

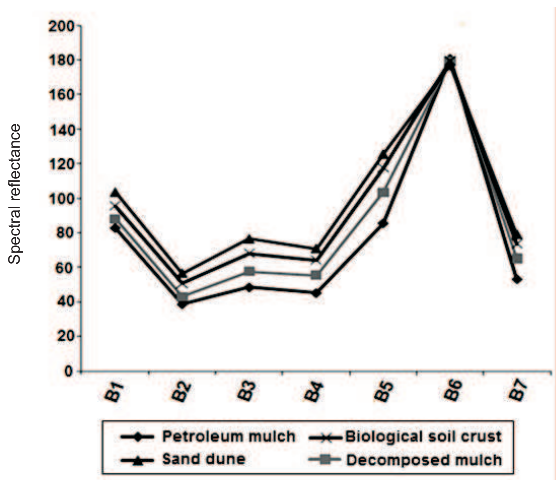

Fig. 5. Spectral signature of different features in study area.

Band ratio images by thermal band have been illustrated in Fig. 7. As illustrated in these figures, difference between petroleum mulch reflectance in thermal band and visible bands caused that petroleum mulch clearly appear red by band ratio technique. The coverage of thin mulch layer on sand dunes caused different behaviours in the mulched area in comparison to other areas. Because of bareness of area and vertical sunshine on petroleum mulch, a high amount of sun radiation is absorbed leading to the increase of heat in this area. Distribution of this heat to the surrounding environment causes the different behaviour of mulched area in thermal band from other bands. Results of field observation showed that mulched area was different in appearance and surface properties from the surrounding area. These areas have been distinguished by a highly dark colour on surface from the surrounding area (Fig. 8). Results of petroleum mulching reflectance in TM and ETM sensors showed that petroleum mulches have an almost similar spectral reflectance in visible, infrared and near infrared, but in TIR (thermal infrared)band that is completely different. The most differences are in the green and thermal bands (Fig. 9). By attention to this difference and through band ratio technique, RMI was defined for clarifying the petroleum mulch. Comparison of RMI information from mulched area with field observation explains efficiency of RMI for clarifying petroleum mulch in desert area, while annually a wide range of these deserts are fixed and rehabilitated by petroleum mulch in Iran. According to field study, and data analysis 213 ha of sand dunes were fixed, and 1 153 ha of the study area converted to forest in 1 991 by mulching, also 218 ha of sand dunes were fixed, and 1 481 ha of these areas converted to forest by mulching in 2002, too.

Assessment bare soil indices capacity to clarify petroleum mulch including BSI (bare soil index) showed that although the areas covered with mulch has different physicochemical properties of sand dunes with other area, these indices and BSI cannot distinguish between mulched areas with other areas in desert of Iran. Also, comparison between RMI and BSI in the two regions with similar geographical latitude showed that BSI not only could not distinguish between mulched and non-mulched areas but also classified sand dunes areas in mulched areas revealing the contrast between obtained results and field observations (Fig. 10).

Petroleum mulch in the fixation of sand dune and desertification is a national and local experience and has features specific to it. Petroleum mulch is being decomposing by time and reverts to the initial status. Hence, BSI is not

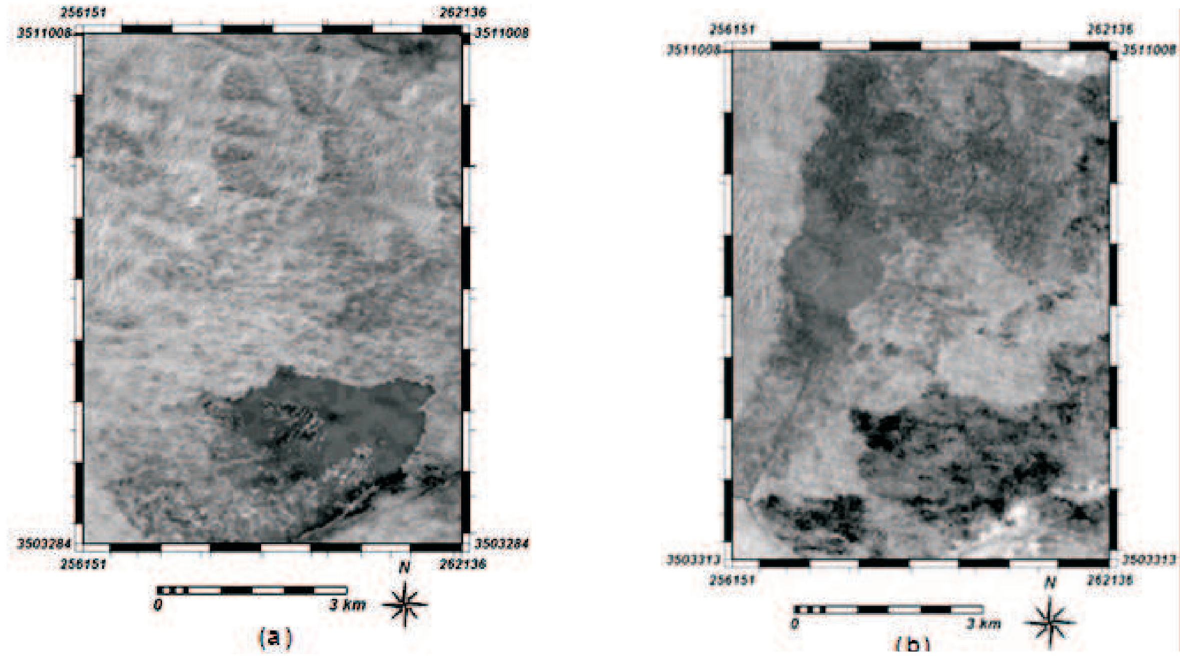

Fig. 6. False colour composite images (ECC), a – FCC (643) TM 1991, b – FCC (643) ETM 2002.

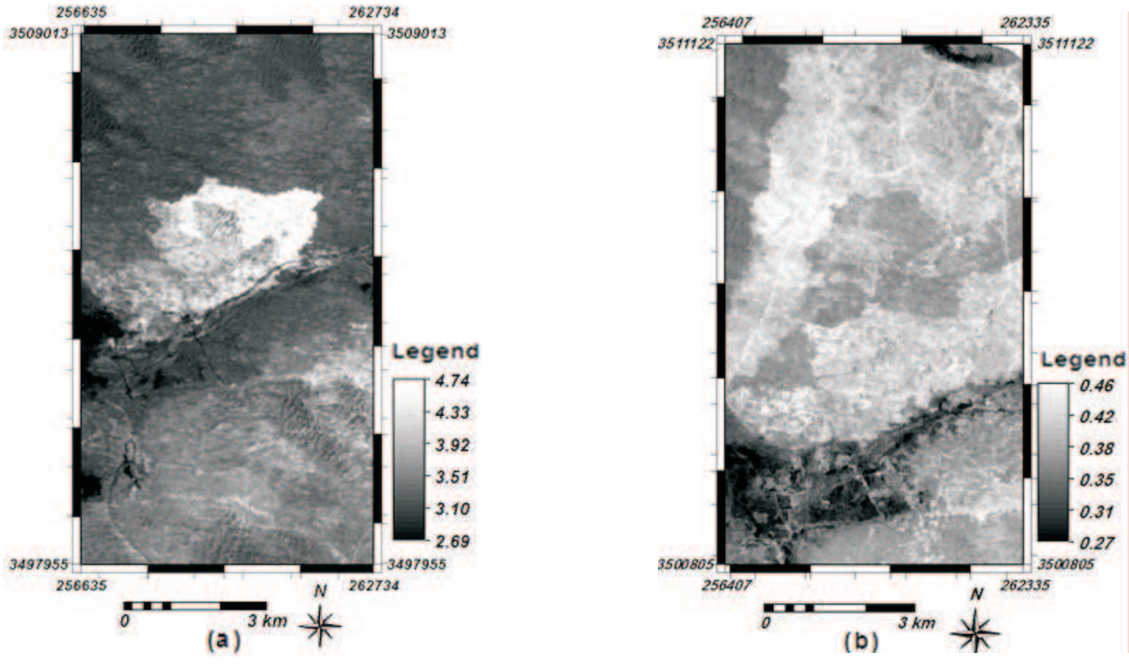

Fig. 7. Band ratio images to clearance petroleum mulch: a – band ratio (TM6-TM2)/(TM6+TM2) 1991, b – band ratio (ETM6-ETM2)/(ETM6+ETM2), 2002.

suitable due to complicated behaviour of petroleum mulches. Due to two dimensions distribution of soil pixels, the major changes in soil surface come to surface after mulching. So, according to the differences in spectral behaviour of petroleum mulches in thermal and green bands with TM and ETM, using suitable RMI is necessary in deserts of Iran to manage the mulching process. RMI, in addition to illustrating mulching process, could be useful in evaluating and managing mulching process and mulch decomposition after time. Due to intricacy of petroleum mulches behaviour in appearance and chemical properties after being used in desert surface and lack of proper data

Fig. 8. Images of field study area mulching for comparing appearance properties between mulch and non-mulch area.

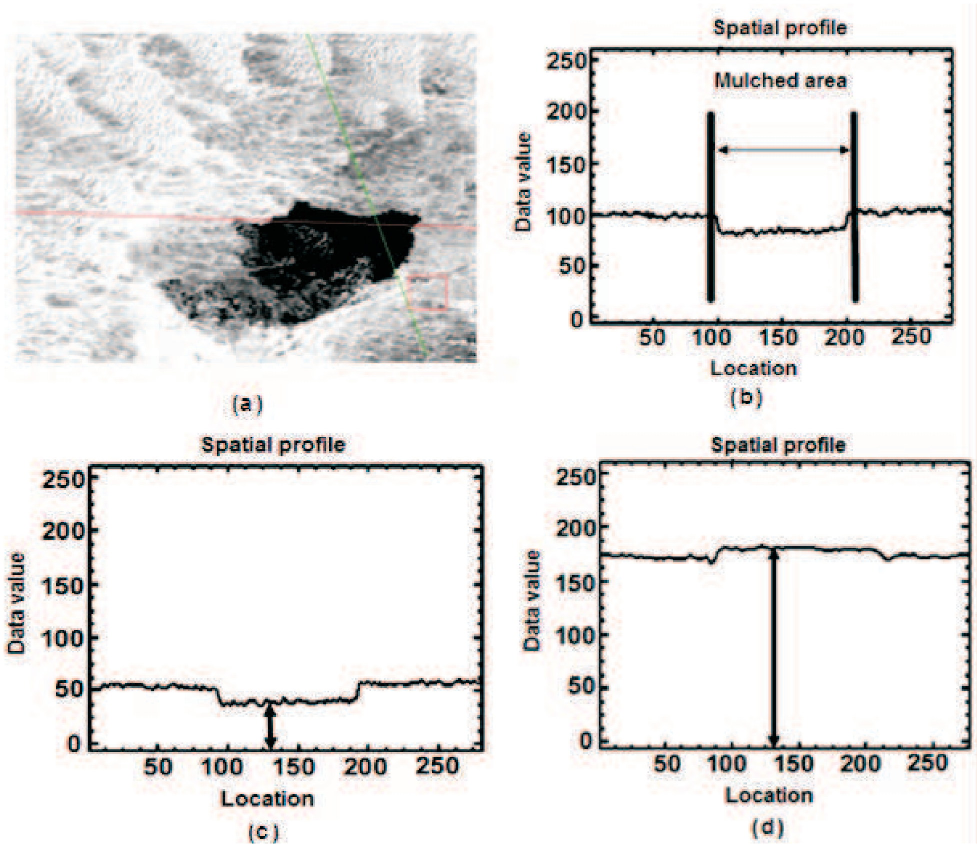

Fig. 9. Profile spectrum reflectance from: a – petroleum mulch TM 1991, b – TM1, c – TM2, d – TM6.

about this petroleum substance, provided indices such as BSI could not illustrate mulched areas, and generally different properties of petroleum mulch have been disregarded in defined indices of deserted areas. By attention to vast desert area of Iran, mulching processes for sand dunes fixation and creation of vegetation cover requires a decent management. In addition, mulching should be carried out systematically and correctly regarding the suitable distribution and thickness in desert surface, so that, after fixation of the areas, petroleum mulch would be decomposed and mulched area would return to its initial status preventing permanent changes in environment, and petroleum mulch could be used only for creation of vegetation cover, and then it could be decomposed. Hence, employing a suitable index is needed for investigation of these area operations.

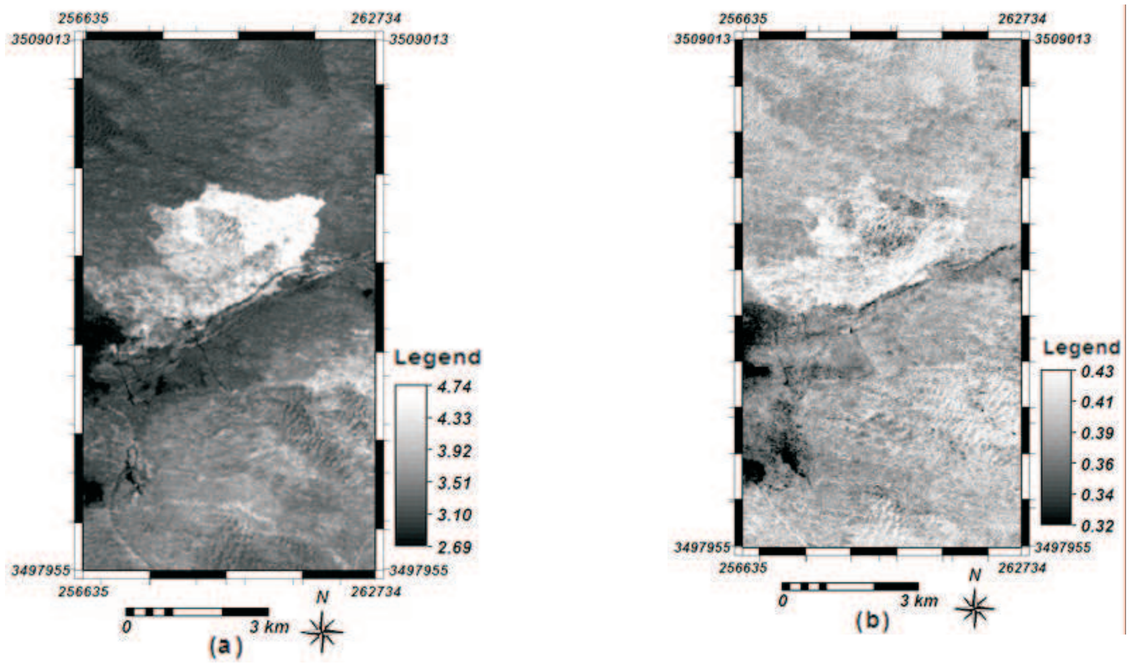

Fig. 10. Image of: a – RMI TM 1991, b – BSI TM 1991.

CONCLUSIONS

1. According to visual interpretation landsat TM/ETM could separate mulched and unmulched area obviously. Since mulching process is so extensive, using remote sensing data would be helpful to manage mulched area, also it can decrease the time and costs of field observation.

2. Landsat ETM with one thermal band 6 in the atmosphere window of 10.4–12.5μm was used for deriving the best band combination for clarifying petroleum mulch on sand surface in desert area of Iran. Picture of RMI has shown that using thermal band is useful to show petroleum mulch as a synoptic view in desert area.

3. In order to evaluate the impact of using band ratios for clarifying petroleum mulch in desert area of Iran different band combinations were used and compared with bare soil indices. As thermal band has low correlation with visible bands, regarding this hypothesis, different band combinations between visible and thermal bands by band ratio operation were formed. Finally, based on field observation and comparison with other arid indices, RMI was introduced as an index for local study in desert area of Iran. This index can differentiate mulch from other existing phenomena of region like sand dunes, biological crust and manually planted forests. In addition, when this index is applied in Iran deserts, the process of mulch decomposition, distinct characteristics of mulch, is detectable and identifiable.

REFERENCES

Brady N.C. and Weil R.R., 1999. The Nature and Properties of Soils. Prentice Hall Press, Upper Saddle River, NJ, USA.

Cheng K.S. and Lei T.C., 2001. Reservoir trophic state evaluation using Landsat TM images. J. Am. Water Res. Assoc., 37(5), 1321-1334.

Czyż E.A. and Dexter A.R., 2009. Soil physical properties as affected by traditional, reduced and no-tillage for winter wheat. Int. Agrophysics, 23, 319-326.

Dahiya R., Ingwersen J., and Streck T., 2007. The effects of mulching and tillage on the water and temperature regimes of a loess soil: experimental findings and modeling. Soil Till. Res., 96, 52-63.

Daniel K.W., Tripathi N.K., Honda K., and Apisit E., 2004. Analysis of VNIR (400–1100 nm) spectral signatures for estimation of soil organic matter in tropical soils of Thailand. Int. J. Remote Sensing, 25, 643-652.

Diaz F., Jimenez C.C., and Tejedor M., 2005. Influence of the thickness and grain size of *tephra* mulch on soil water evaporation. Agric. Water Manag., 74, 47-55.

Dunn B.W., Beecher H.G., Batten G. D., and Ciavarella S., 2002. The potential of near-infrared reflectance spectroscopy for soil analysis – a case study from the Riverine Plain of south-eastern Australia. Australian J. Exp. Agric., 42, 607-614.

Eklundh L. and Olsson L., 2003. Vegetation trends for the African Sahel in 1982-1999. Geophys. Res. Letters, 30, 1430-1434.

Geerken R. and Ilaiwi M., 2004. Assessment of rangeland degradation and development of a strategy for rehabilitation. Remote Sensing Environ., 90, 490-504.

Herman S.M., Anyamba A., and Tucker C.J., 2005. Recent trends in vegetation dynamics in African Sahel and their relationship to climate. Global Environ. Change, 15, 394-404.

Hostert P., Röder A., Hill J., Udelhoven T., and Tsiourlis G., 2003. Retrospective studies of grazing-induced land degradation: a case study in central Crete, Greece. Int. J. Remote Sensing, 24(20), 4019-4034.

Jensen J.R., 1996. Digital Image Processing. Prentices Hall Press, Upper Saddle River, NJ, USA.

Josa R., Ginovart M., and Solé A., 2010. Effects of two tillage techniques on soil macroporosity in sub-humid environment. Int. Agrophys., 24, 139-147.

Mulumba L.N. and Lal R., 2008. Mulching effects on selected soil physical properties. Soil Till. Res., 98, 106-111.

Oyedele D.J. and Tijani F.O., 2010. Spatial and temporal variability of soil water content. Int. Agrophys., 24, 171-176.

Petit C., Scudder T., and Lambin E., 2001. Quantifying processes of land-cover change by remote sensing: resettlement and rapid land-cover changes in south-eastern Zambia. Int. J. Remote Sensing, 22(17), 3435-3456.

Ray T.W., 1995. Remote sensing of land degradation in arid/semiarid regions. Ph.D. Thesis, California Institute of Technology, USA.

Rees H.W., Chow T.L., Walker D.F., and Smith O.M., 1999. Potential use of underseeded barley to increase carbon inputs to a loam soil in New Brunswick potato belt, Canada. Can. J. Soil. Sci., 79, 211-216.

Röder A., Kuemmerle T., Hill J., Papanastasis V.P., and Tsiourlis G.M., 2007. Adaptation of a grazing gradient concept to heterogeneous Mediterranean rangelands using cost surface modelling. Ecological Modelling, 204(3-4), 387-398.

Röder A., Udelhoven T., Hill J., Del Barrio G., and Tsiourlis G.M., 2008. Trend analysis of Landsat-TM and -ETM+ imagery to monitor grazing impact in a rangeland ecosystem in Northern Greece. Remote Sens. Environ., 112, 2863-2875.

Roy S.K., Shibusawa S., and Okayama T., 2006. Textural analysis of soil images to quantify and characterize the spatial variation of soil properties using a real-time soil sensor. Precision Agric., 7, 419-436.

Said-Al Ahl H.A.H. and Abdou M.A.A., 2009. Impact of water stress and phosphorus fertilizer on fresh herb and essential oil content of dragonhead. Int. Agrophysics, 23, 403-407.

Stamatiadis S., Christofides C., Tsadilas C., Samaras V., Schepers J.S., and Francis D., 2005. Groundsensor soil reflectance as related to soil properties and crop response in a cotton field. Precision Agric., 6, 399-411.

Tejedor Salguero M., Jimenez C.C., and Diaz Pena F., 2003. Soil moisture regime changes in *tephra* mulched soils: Implication for soil taxonomy. Soil Sci. Soc. Amer. J., 66, 202-206.

Yamarak T., Inoue M., and Kaihotsu I., 2004. Effects of gravel mulch on water vapor transfer above and below the soil surface. Agric. Water Manag., 67, 145-155.