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Determination of Treeline Using Satellite Data and Field Techniques (A Case Study; Western Nojomeh, Iran)

[1]K. Solaimani and [2]S. Lotfi
[1]University of Agriculture and Natural Research Sciences, P.O. Box 737, Sari, Iran
[2]Department of Geography, University of Mazandaran, Babolsar, Iran

Abstract: The aim of this study was capability investigation of the satellite KFA-1000 colour and panchromatic images to determine an elongated tree border of two different vegetation communities of forest and rangeland, which have resulted from a natural and anthropogenic environmental gradient in northern flank of Alborz range. In this study we investigate the use of stereoscopic mapping to produce a classification of a tree line ecotone in Northern Alborz Mountains of Vazroud Basin using visual images which has supported with the field investigation as ground control in June 2008 as well. From north toward south parts the transition with altitude is from dense forest to treeless rangeland and herbaceous vegetation. The relationships between the probability of class membership for the two end-member classes of scrub and forest and rangeland and the percentage ground cover of these vegetation classes were highly significant: $r^2 = 0.89$ and $r^2 = 0.95$, respectively.

Key words: Classification, tree line, KFA-1000, aerial photos

INTRODUCTION

The tree line or timberline is the edge of the habitat at which trees are capable of growing. Beyond the tree line, they are unable to grow because of inappropriate environmental conditions (usually cold temperatures, insufficient air pressure, or lack of moisture). An ecotone is a transition area between two adjacent ecological communities or ecosystems. It may appear on the ground as a gradual blending of the two communities across a broad area, or it may manifest itself as a sharp boundary line. In visual space data of the aerial photographs and KFA-1000, an ecotone may appear as an edge, a boundary of mixed pixels or a zone of continuous variation, depending on the spatial scale of the vegetation communities and their transition zone in relation to the spatial resolution of data. Often in image stereoscopic interpretation, an ecotone is observed clearly, or part of it may be mapped as a separate vegetation community if it covers an area of several pixel widths. A soft classification method, such as probability mapping, is inherently appealing for mapping vegetation transition. Ideally, the probability of membership each pixel has to each vegetation class corresponds with the proportional composition of vegetation classes per pixel.

Clements (1905) was introduced ecotone as a zone of transition between two individual vegetation communities. These unique ecosystems can have higher biodiversity than either neighbouring community (Beckage *et al*., 2008) which helps maintain species flows between them (Baker *et al*., 2002). Furthermore, ecotones can influence the flux of materials and energy in the landscape and can be early indicators of ecological response to environmental change (Di Castri *et al*., 1988). The determination and monitoring of ecotones therefore has a crucial role in our understanding of biodiversity distribution and the policies that are put in place to enhance it. Ecotones can be classified as environmental or anthropogenic, resulting from either natural or human-induced

Corresponding Author: K. Solaimani, University of Agriculture and Natural Research Sciences, P.O. Box 737, Sari, Iran Tel: +989111521858

environmental transition over space, as invasion where there is invasion of a dominant species along a front, or as switch where there is a positive feedback between vegetation community and environment (Walker *et al*., 2004). The transition with altitude from dense forest to the rangeland represents an ecotone gradient relating to increasingly harsh environmental conditions (Smith *et al*., 2003). Clearly, where an ecotone is determined by an environmental gradient, its nature and spatial configuration are highly susceptible to environmental change (Malanson, 2001). Despite of human impacts also the local scale environmental factors such as topographic complexity, geology, disturbance patterns and biotic interactions will influence as relevant (Alftine and Malanson, 2004; Wu *et al*., 2007). A more thorough examination of ecotones in remotely sensed imagery was provided by Allen and Walsh (1996). They investigated the treeline ecotone in Glacier National Park, Montana, using two Landsat TM images. They used a hierarchical approach to create a supervised classification of six forest types and five non-forest vegetation types. In fact, there is no analogy between hard classification methods applied to vegetation analysis in remotely sensed data and the ordination methods commonly used in vegetation analysis, which examine gradients of change between vegetation communities (Nelson *et al*., 2004; Wiegand *et al*., 2006). Hard classification is wasteful of information generated on the strength of class membership, which can partially reflect the land-cover composition of mixed pixels in boundary or ecotone areas (Foody, 1996). The probability information can be used to soften the output of a hard classifier by outputting the probabilities of membership each pixel has to each class (Foody, 1992). Alternatively, soft techniques exist such as linear-mixture modelling (Quarmby *et al*., 1992) or fuzzy cmeans clustering (Cannon *et al*., 1986) which seek to unmix the composition of pixels, for example, at land-cover boundaries. The relationship between the output of these techniques and the proportional composition of land-cover per pixel will depend on the spectral separability of the chosen end-member land-cover types and the ability of these to depict the structural and floristic complexity of the land-cover types present (Fisher and Pathirana, 1990; Foody and Cox, 1994). Ranson *et al*. (2004) used a Landsat Enhanced Thematic Mapper (ETM+) image, amongst others, for assessing the tundra-taiga ecotone in Russian Siberia. They performed a hard classification of six land-cover classes (water bodies, taiga, tundra, bogs, riparian vegetation and sand bars) to create a mask of taiga and tundra pixels. A linear-mixture model was then applied to the masked 7-band ETM+ image based on the end-member classes of dense taiga forest and treeless tundra. The classification probability or membership function for a vegetation class may correspond with the proportional composition of that vegetation class for the area covered by a pixel. However, the probability or membership image for a vegetation class cannot by itself represent an ecotone, since an ecotone is a transition from one vegetation type to another. However, this must take into account both end-member classes and it places subjective hard boundaries onto the landscape. The decision of where to delineate the alpha-cuts will have a significant impact on the spatial characterisation of an ecotone and any derived landscape pattern metrics (Arnot *et al*., 2004; Shi *et al*., 2008). There is no optimal method of delineating ecotone boundaries (Fortin *et al*., 2000) and yet to understand the processes involved in the formation and maintenance of ecotones and to monitor their stability over time, it is necessary to delineate them accurately (Fortin and Drapeau, 1995). This study investigates the use of class probability mapping to produce a classification of an ecotone in Alborz using a KFA-1000 and aerial photos. It can be mapped for the treeline ecotone as a zone of transition of some intermediate vegetation classes between forest and treeless vegetation.

MATERIALS AND METHODS

Study Area and Material

The field site is located in the Northern flank of Alborz Mountains, Iran, in the south of the Caspian Sea. The area lies in the Central Alborz, where is mainly sandstone rocks and clay. The field

Fig. 1: Geographical location of the study area (June 2008)

site includes two ecosystem regions from highland to the forest zone, all within the Central Alborz zone. In the high mountains, the dominant vegetations are related to the rangeland and the forest area is covered by broadleaf species (Fig. 1). The satellite remotely sensed image of Cosmos used in this research was a colour and panchromatic KFA-1000 scene acquired on July 1991. The KFA-1000 camera system acquires colour and panchromatic spectrozonal photography from an average height of 270 km with an average scale of 1:270000. The frame size is 30×30 cm. covering an area of 6400 km^2 with 60% longitudinal overlap of photographs. This study was completed using both of the mentioned data and field investigation in June 2008.

The ground resolution of this photography is 5 to 10 m and it has spectral range of 570-680 nm and 680-810 nm. The camera number, focal length and exposure number appear in each frame as well (Solaimani, 2001). Also the panchromatic band of the same data was used to determine the treeline for the calculation of a 7 m spatial resolution. The mentioned two multi-spectral and panchromatic KFA-1000 images were corrected for differential terrain illumination, using aerial photographs, topography map at 1:50000 scale and also the field investigations.

Methods

A total of 32 training areas were identified in the field to capture the stereoscopic variance of the used images scene components. These included components that were not relevant to mapping the ecotone (cloud shadow, water bodies, bare soil, pasture and river channels) and components that were of relevance (bare rock, sparse herbaceous vegetation, natural grass, scrub and forest of different age and species composition). These training data were used for visual classification of the two colour and panchromatic images. Due to the remote and rugged nature of the field site and difficulty of enumerating field plots on a large scale, validation data for this study were derived from high spatial resolution aerial photographs and the extended field assessment. This is a standard practice in studies validating the output of an image classification (e.g., Foody *et al*., 2003; Wang, 1990). Two separate tests were carried out to investigate whether the posterior probabilities of class membership related to vegetation composition; the first at a pixel level (i.e., 10×10 m) and the second at a quadrat level (i.e., up to 200×200 m). To identify whether the posterior probability of scrub and forest related to the proportional cover of trees and shrubs per pixel, a crown mask was produced at 6 m spatial resolution by applying a stereoscopic view to the panchromatic band and an upper to the colour images of KFA-1000. This provided the proportional crown cover in sixteenths per 10 m pixel of the scrub and forest probability image. To identify whether the posterior probabilities related to the proportional vegetation cover per quadrat, two scanned and ortho-rectified, 1:20000 scale, colour aerial photographs were used to derive the proportional cover of (i) trees and shrubs and (ii) grass and herbaceous vegetation in 12 sample quadrats. These quadrats ranged in size from 50×80 m to 200×200 m and were located at different elevations and in differing densities and distributions of tree and shrub canopy cover. For each quadrat a regularly spaced grid of ten horizontal and vertical transects were marked and at each intersect (totaling 50) the land-cover was identified visually as trees/shrubs, grass/ herbaceous vegetation, or non-vegetated. The distinction between trees and shrubs and between grass and herbaceous vegetation could not be made routinely by this visual interpretation method. This analysis gave an estimate of the percentage canopy cover of trees/shrubs and of grass/herbaceous vegetation per quadrat. Relationships were examined between the average posterior probability for scrub and forest and for the two non-forest vegetation classes combined. This indicated the significance of the posterior probabilities of class membership at a spatial scale greater than that of the individual pixel.

Representing of the Treeline Ecotone

For this study the treeline ecotone was considered as a transition between upland examples of scrub and forest and the non-forest vegetation classes of pasture and natural grass and sparse herbaceous vegetation. For ease, the posterior probability of class membership for pasture and natural grass and sparse herbaceous vegetation are combined as a single vegetation class (called non-forest vegetation) for the remainder of this paper. To map this transition two different approaches were used, although both approaches were applied only to those pixels for which the combined posterior probability for scrub and forest and non-forest vegetation was 90%. In the first approach, stereoscopic method were applied to the posterior probability of scrub and forest to separate two end member vegetation communities and the transitional classes.

RESULTS AND DISCUSSION

The red treeline were extracted on both panchromatic and colour images for scrub and forest, pasture and natural grass and sparse herbaceous vegetation is determined clearly with better resolution in colour KFA-1000 image than the gray one. The grey scale images of the KFA-1000 in dark tones have low resolution of probability border of the forest in class membership and the colour tones have high resolution (Fig. 2-4).

In these probability images, the boundaries are diffuse (ecotones) between scrub and meadow/herbaceous vegetation in the upland areas. The two colour and panchromatic images show a decrease in the natural border line of different vegetation cover of forest and rangeland types and a corresponding increase for grass and/or herbaceous vegetation with increasing elevation. The proportional cover of trees/shrubs and of grass/ herbaceous vegetation in the 12 quadrates sampled in

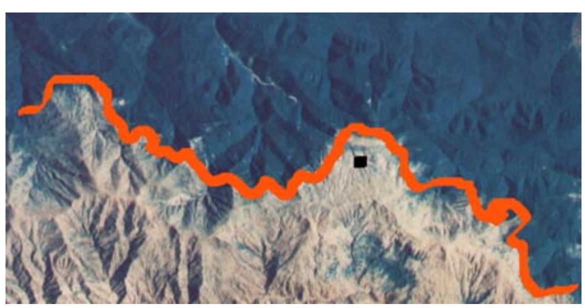

Fig. 2: Western Nojomeh treeline marked with red line (source; colour KFA-1000 of 3 June 1990)

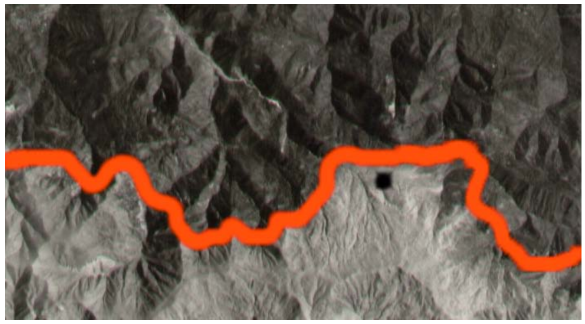

Fig. 3: Western Nojomeh treeline marked with red line (source; Pan. KFA-1000 of 3 June 1990)

Fig. 4: Treeline ecotone of the study area

the aerial photographs ranged from 90 and 6%, respectively to 9 and 89%, respectively. The relationships between the posterior probability of class membership for scrub and forest and nonforest vegetation and the percentage ground cover of these vegetation classes were positive and highly significant: $r^2 = 0.84$ and $r^2 = 0.86$, respectively. Although the posterior probability image for scrub and forest was shown to be meaningful in terms of forest composition, this was not by itself adequate to represent fully the treeline ecotone, since the transition was between scrub and forest and the non-forest vegetation classes of pasture. This would be expected given the offsets in the relationships between posterior probabilities and the quadrate data, which were compounded by calculating ratios.

CONCLUSIONS

Stereoscopic visual probability of class membership from a standard classification can enable a much more detailed characterisation of an upland treeline ecotone than a traditional classification. This probability of class membership for scrub and forest was shown to relate to forest and shrub cover per pixel. However, this was not adequate to fully represent the upland treeline ecotone, since the transition was from closed-canopy forest to treeless rangeland and outspread vegetation. Therefore, an ecotone map had to consider the stereoscopic probability for scrub and forest and for the non-forest vegetation classes of pasture and natural grass and sparse herbaceous vegetation. However, the ratio values themselves did not relate very accurately to proportional vegetation cover. Ecotones are often ignored or misrepresented in thematic maps produced using remotely sensed imagery. Representing an ecotone from image classification requires thought on the part of the producer. A user working with thematic products from soft classification requires a greater understanding of the products and their method of production than with standard thematic maps. This issue of how to derive spatial statistics on an ecological transition between two vegetation communities that, by definition as an ecotone, have no clearly defined spatial boundaries remains to be addressed.

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REFERENCES

Alftine, K.J. and G.P. Malanson, 2004. Directional positive feedback and pattern at an alpine tree line. J. Veg. Sci., 15: 3-12.

Allen, T.R. and S.J. Walsh, 1996. Spatial and compositional patterns of Alpine treelines, Glacier National Park, Montana. Photo. Eng. R.S., 62: 1261-1268.

Arnot, C., P.F. Fisher, R. Wadsworth and J. Wellens, 2004. Landscape metrics with ecotones: Patterns under uncertainty. Lan. Ecol., 19: 181-195.

Baker, J., K. French and R.J. Whelan, 2002. The edge effect and ecotonal species: Bird communities across a natural edge in Southeastern Australia. Ecology,. 83: 3048-3059.

Beckage, B., B. Osborne, D.G. Gavin, C. Pucko, T. Siccama and T. Perkins, 2008. A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. PNAS, 18: 4197-4202.

Cannon, R.L., J.V. Dave, J.C. Bezdek and M.M. Trivedi, 1986. Segmentation of a thematic mapper image using the fuzzy c-means cluster algorithm. IEEE Trans. Geosci. R. S., 24: 400-408.

Clements, F.E., 1905. Research Methods in Ecology. 1st Edn., University Pub. Co., Lincoln, Nebraska.

Di Castri, F., A. Hansen and M.M. Holland, 1988. A new look at ecotones: Emerging international projects on landscape boundaries. Biol. Int. Spec. Iss., 17: 1-163.

Fisher, P.F. and S. Pathirana, 1990. The evaluation of fuzzy membership of land cover classes in the suburban zone. R. S. Environ., 34: 121-132.

Foody, G.M., 1992. A fuzzy set approach to the representation of vegetation continua from remotely sensed data: An example from lowland heath. Photo. Eng. R. S., 58: 221-225.

Foody, G.M. and D.P. Cox, 1994. Sub-pixel land cover composition estimation using a linear mixture model and fuzzy membership functions. Int. J. Remote Sens., 15: 619-631.

Foody, G.M., 1996. Fuzzy modelling of vegetation from remotely sensed imagery. Ecol. Mod., 85: 3-12.

Foody, G.M., R.G. Jackson and C.P. Quine, 2003. Potential improvements in the characterisation of forest canopy gaps caused by windthrow using fine spatial resolution multispectral data: Comparing hard and soft classification techniques. For. Sci., 49: 444-454.

Fortin, M.J. and P. Drapeau, 1995. Delineation of ecological boundaries: Comparison of approaches and significance tests. Oikos, 72: 323-332.

Fortin, M.J., R.J. Olson, S. Ferson, L. Iverson, C. Hunsaker and G. Edwards, 2000. Issues related to the detection of boundaries. Lan. Ecol., 15: 453-466.

Malanson, G.P., 2001. Complex responses to global change at alpine treeline. Phys. Geog., 22: 333-342.

Nelson, D.M., F. Sheng, H.J. Tian, I. Stefanova and T.A. Brown, 2004. Response of C3 and C4 plants to middle-Holocene climatic variation near the prairie-forest ecotone of Minnesota. PNAS, 101: 562-567.

Quarmby, N.A., J.R.G. Townsend, J.J. Settle, K.H. White and M. Miling *et al*., 1992. Linear mixture modelling applied to AVHRR data for crop area estimation. Int. J. Remote Sens., 13: 415-425, 466.

Ranson, K.J., G. Sun, V.I. Kharuk and K. Kovacs, 2004. Assessing tundra-taiga boundary with multi-sensor satellite data. Remote Sensing Environ., 93: 283-295.

Shi, P., C. Körner and G. Hoch, 2008. A test of the growth-limitation theory for alpine tree line formation in evergreen and deciduous taxa of the eastern Himalayas. Func., Ecol., 22: 213-220.

Smith, W.K., M.J. Germino, T.E. Hancock and D.M. Johnson, 2003. Another perspective on altitudinal limits of alpine timberlines. Tree Phys., 23: 1101-1112.

Solaimani, K., 2001. Application of satellite photographs in morphotectonic study of the Central Alborz, Iran. 22nd Asian Conference on Remote Sensing. Nov. 5-9, Singapore pp: 1-3.

Walker, S., J. BastowWilson, J.B. Steel, G.L. Rapson and B. Smith *et al*., 2004. Properties of ecotones: Evidence from five ecotones objectively determined from a coastal vegetation gradient. J. Veg. Sci., 14: 579-590.

Wang, F., 1990. Improving remote sensing image analysis through fuzzy Photo. Eng. Remote Sens., 56: 1163-1169.

Wiegand, T., J. Camareo, N. Ruger and E. Gutierrez, 2006. Abrupt population changes in treeline ecotones along smooth gradients. J. Ecol., 94: 880-892.

Wu, H., J. Guiot, S. Brewer, Z. Guo and C. Peng, 2007. Dominant factors controlling glacial and interglacial variations in the treeline elevation in tropical Africa. PNAS, 104: 9720-9724.