# Curriculum Vitae

**Name:** Parviz Zeaiean Firouzabadi

Nationality: Iranian
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Dept. of Remote Sensing and GIS
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## Academic Qualifications

- 1998. Ph.D., Civil Engineering, Institute for Ocean Management, Civil Engineering Department, Anna University, Madras India. The Ph.D. thesis entitled: Digital approaches for change detection in urban environments using remote sensing data.
- 1994. Master of Technology in Remote Sensing, Institute of Remote Sensing, Civil Engineering Department, Anna University, Madras India. The M.Tech. Thesis entitled: software development for fuzzy classification technique and its application to urban area.
- 1990. B.E., Mineral Exploration, Mining Engineering Department, Isfahan University of Technology, Isfahan, Iran.

## Professional Experiences

- **2013-Present** Head, Department of Remote Sensing and GIS, Kharazmi University (Tarbiat Moallem University), Tehran Iran.
- **2013-2014** Director, Research Affairs, Kharazmi University (Tarbiat Moallem University), Tehran Iran.
- **2010-Present** Associate Professor, Faculty of Geographical Sciences, Kharazmi University (Tarbiat Moallem University), Tehran Iran.
- **2008-2010** Assistant Professor, Department of Geography, Kharazmi University (Tarbiat Moallem University) Tehran, Iran.
- **2006-2008** Assistant Professor, Remote Sensing & GIS Department, Shahid Beheshti University Tehran Iran.
- **2000-2006** Assistant Professor, Department of Geography, Kharazmi University (Tarbiat Moallem University) Tehran, Iran.
- **2000-2004** Head, Remote Sensing and GIS Division, Office of Statistics and Information Technology, Ministry of Agriculture Tehran Iran.
- **1997-2000** Remote sensing and GIS expert with Ministry of Agriculture, Tehran Iran.

## Teaching Experiences

| *Courses* | **Level** | **University** | **No. of Semesters** |
|---|---|---|---|
| ***Principles of Remote Sensing*** | B.Sc. Geography, B.Sc. Surveying | Tarbiat Moallem University/K.N.Toosi University of Technology Tehran | 12 |
| ***Interpretation of Aerial photos*** | B.Sc. Geography | Tarbiat Moallem University/Tehran | 12 |
| ***Satellite Image Processing*** | M.Sc. Remote Sensing and GIS | Tarbiat Modares University/Shahid Beheshti University Tehran | 8 |
| ***Geographical Information Systems(GIS)*** | PhD/M.Sc. Geography/Geology | Tarbiat Moallem University/Tehran | 10 |
| ***Surveying1/ surveying2*** | B.Sc. Geography | Tarbiat Moallem University/Tehran | 8 |
| ***Geomatic Engineering (GIS/GPS/RS)*** | M.Sc. CCD | Maleke Ashtar University-Tehran | 4 |
| ***Computer for Geography students*** | B.Sc./M.Sc. Geography | Tarbiat Moallem University/Tehran | 2 |
| ***Computer programming*** | PhD Geography/M.Sc. Remote Sensing | Tarbiat Moallem University/Tehran | 2 |
| ***Spatial analysis in GIS*** | Ph.D. Geography | Tarbiat Moallem University/Tehran | 1 |
| ***Quantitative Remote Sensing*** | Ph.D. Remote Sensing | K.N.Toosi University of Technology/ Tehran | 1 |
| ***Advanced Image Processing*** | M.Sc. Remote Sensing | JIK program, ITC Netherlands K.N.Toosi University of Technology | 1 |
| ***English language*** | M.Sc. Remote Sensing | Shahid Beheshti University Tehran | 1 |
| ***Mathematics/Applied Mathematics*** | B.Sc./M.Sc. Geography | Tarbiat Moallem University/Tehran | 4 |

## Lectures in workshops/Short courses

| Workshop/Short courses | Place | Year | No. of Participants |
|---|---|---|---|
| ***Application of Statistics in Remotely Sensed Data analysis*** | 4th Iranian statistics conference, Shahid Beheshti University, Tehran Iran | 1998 | 30 experts from statistical departments |
| ***Applications of Remote Sensing, GPS and GIS in crop acreage estimation*** | Ministry of Agriculture-Tehran Iran | 1999-2000 | 120 agricultural experts from provincial agricultural organizations |
| ***Applications of Remote sensing in Agricultural field*** | Ministry of Agriculture-Karj-Iran | 2004 | 70 experts from institutes of agricultural research |
| ***GPS fundamentals and applications*** | Tarbiat Modares University-Tehran Iran | 2008 | 35 experts from Tehran Municipality |
| ***GIS for Veterinary management*** | Minstry of Jahad-e-Agriculture, Tehran Iran | 2010 | 90 experts from provincials veterinary organizations |

**Computer knowledge**

**Programming languages: FORTRAN, Matlab, C, Basic, Easi modelling. Software Packages: Geomatica, Arc/GIS, Arc/info, Arc/view, Pamap, Idrisi, R2V, Surfer and UNIX shell programming**
**OS: Windows, UNIX.**

# Publications

## BOOK CHAPTER

- Graham A. Tobin and Burrell E. Montz (eds.) 2015. Evolving Approaches to Understanding Natural Hazards. CHAPTER 24, Cambridge Scholars Publishing

## BOOKS

- ***Parviz Zeaiean Firouzabadi***, *Nader Parvin*, "Principles of the Remote Sensing sciences (Air photos and satellite images)", Payame Noor University, Tehran Iran, 2007( in Persian).
- ***Parviz Zeaiean Firouzabadi***, "Study on the spectral characteristics of different crops in Hamadan province of Iran using remote sensing data" Two Volumes Published by Ministry of Agriculture Tehran Iran. 1998. ( in Persian).
- Editing of a portion of a book translated to Persian entitled "sampling methods for agricultural surveys'2000.Published by FAO. ( in Persian).

## Course Materials

- Translation of course materials for MIT open course ware (OCW) entitled " A workshop on geographic information systems" Fall 2005, 11520/11.188. Available at: http://mit-ocw.sbu.ac.ir/Default.aspx?tabid=4034.
- Course materials for remote sensing subjects for B.Sc. students (in Persian)

## Journals

1. Ramachandran, S., Krishnamoorthy, R., Sundaramoorthy, S., Zeaiean Firouzabadi, P., Kalyanamuthiah, A. and K. Dharanirajan. (1997) " Management of Coastal Environments in Tamilnadu and Andaman and Nicobar Islands Based on Remote Sensing and GIS Approaches", *MAEER'S MIT Pune Journal*, Vol., IV(Nos.15&16) special issue on coastal environment management, Pune, India, pp129-140.

2. Zeaiean Firouzabadi, P. and Saroei, S., (2003). Evaluating the potentials of remote sensing and GIS technologies in land use land cover mapping of Shadegan Marshes(Text in Persian). *Journal of Geographical Sciences*, vol.1, No.2.

3. Mousavi, A., Zeaiean Firouzabad, P., shakiba A. and Naseri, A. (2003). Flood Prone Areas Simulating Using Remote Sensing Data and Cellular Automata Model (Case Study : Talar RiverBasin-Iran), *Geography*, vol.1. (Text in Persian)

4. Rabiei H.R., Zeaiean, P. and Alimohammadi, A. (2005). Detection of land use/cover of Isfahan by agricultural lands around urban areas using remote sensing and GIS technologies" (Text in Persian), *Modares Human sciences (quarterly journal Geography)*, vol.9,no.3, (tome 43), pp.19-32.

5. Alimohammadi A., Rabiei H.R. and Zeaiean, P. (2005). Modeling uncertainty in change detection based on classification of remote sensing data", (Text in Persian) *Modares Human sciences (quarterly journal-geography)*, vol.9,no.1, (tome 38), spring 2005, 97-110.

6. Zeaiean Firouzabadi, P., Ghanavati, E., (2007). Digital approaches for change detection in urban environment" (Text in Persian), *GEOGRAPHICAL RESEARCH*, 22(1 (84)):pp.133-146.

7. Yazdanpanah H., Hedjazizadeh, Z., Kamali, Gh. and Zeaiean, P.(2007). Determination of climate potential of east Azarbayjan province for rain fed almond using GIS(Text in Persian). *Geography and Development*, vol4, S.No.8, pp193-204.

8. Mobasheri, M.R, Jokar, J., Ziaeian, P. and Chahardoli, M. (2007). On the methods of sugarcane water stress detection using Terra/Aster images, *American-Euroasian J. Agric. Environ. Sci.* 2(3).

9. Mobasheri M. R., Khavarian, H., Zeaiean, P. and Kamali, Gh.(2007). Evapo-Transpiration assessment using Terra/Modis images in the Gorgan general district. *Modares Human sciences (quarterly journal-geography)*, vol.11,no.1, (tome 50), pp.121-142. (Text in Persian)

10. Ghanavati, E., Zeaiean Firouzabadi, P., Alavinejad, S.N.(2007). Khor Mosa Morpho-dynamic and land use change Detection using Remote Sensing and GIS. *Journal of Engineering Geology*, Tarbiat Moallem University, Vol.2,No.2. (Text in Persian)

11. Nazarian A., Zeaiean Firouzabadi, P. and Jangi A.A. (2007). studying the role of geographical site urban morphology on the air pollution of concentration Tehran area with of GIS & RS . *Geographical Research Quarterly*. 39(61):17-30. (Text in Persian)

12. Ashorlo M., Alimohammadi, A., Ziaeian, P. and Ashorlo D. (2007). Application of Linear Discrimination Analysis for Wheat Discrimination from Other Crops on Satellite Images(Text in Persian). *Environmental Sciences*, Vol.4, No.2 , pp101-116

13. Ghanavati, E., Zeaiean Firouzabadi, P., Jangi, A.A. and Khosravi, S. (2008). Monitoring geomorphologic change using Landsat TM data in the Hendijan river delta, southwest Iran. *International Journal of Remote Sensing*, Vol. 29, No. 4, pp.945–959.

14. Dini Gh., Zeaiean Firouzabadi, P., Alimohammadi, A. and Dadashi Khangha S. (2008). GIS-Based Snow Mapping in central Alborz mountain chain using MODIS and AVHRR data(Text in Persian). *Iran-Water Resources Research.* 3(3 (9)): pp.1-8.

15. Bayatani A., Zeaiean Firouzabadi, P., Matkan, A.A., A.Shakiba. (2008). Hydro-thermal alteration mapping using satellite image processing techniques-case study: Meshkinshar-Ahar(Text in Persian). *Iranian Journal of Geology*, 2(7), pp.39-52.

16. Rangzan K., Zeaiean Firouzabadi, P., Mirzaei L. and Alijani F. (2008). Mapping of groundwater vulnerability using drastic and empirical models and assessment of unsaturated zone in GIS: Varamin plain. (Text in Persian). *Iranian Journal of Geology*, 2(6):pp.21-32.

17. Alimohammadi, A., Shamsoddini, A. and Zeaiean, P. (2008). Comparison of spectral and spatial performance of image fusion methods in several difference resolution of multi-spectral and pan images: Tehran (Text in Persian), *Modares Human Sciences (quarterly journal-geography)*, vol.12,no.3, (tome 57), pp.119-138.

18. Ghanavati, E., Zeaiean, P., Sardashti, M., Jangi, A. A. (2008). Morph-dynamic change Detection Using RS, PCA and fuzzy logic case study: Taleghan River Basin(Text in Persian). *Geographical Research quarterly*, No.62, pp41-53.

19. Alimohammadi, A., Matkan,A.A., Zeaiean, P., and Tabatabaii H. (2009). Comparison of method based classification and object base and decision tree in forest type mapping using remote sensing data(case study: Astara forest). (Text in Persian) *Journal of Geographical Sciences*, vol.10, No.13, pp.7-26.

20. Shakiba A, Zeaiean Firouzabadi, P., Ashourloo, D. and Namdari, S. (2009). Analysis of relationship between land use/cover and urban heat island using ETM+(Text in Persian). *Iranian Journal of remote sensing and GIS*, vol.1, no.1.

21. Zeaiean Firouzabadi, P., Shakiba, A. Matkan, A.A. and Sadeghi, A. (2009). Remote Sensing (RS), Geographic Information System(GIS) and cellular automata Model(CA) as tolls for the simulation of urban land use change- a case study of SHAHR-E-KORD(Text in Persian). *Environmental Sciences,* 7(1):133-148.

22. Zeaiean Firouzabadi, P., Sayadbidhendi, L. and Eskandarinoudeh, M. (2009). Mapping and acreage estimation of rice agricultural land using Radarsat satellite images(Text in Persian). *Physical Geography Research Quarterly*, 68,pp.45-58.

23. Zeaiean Firouzabadi, P., Khaledi, Sh., Khandan, S. and Alizadeh, A.(2010). Agro-climatological Zonation of citrus in Lorestan province using index overlay model and fuzzy logic(Text in Persian). *Quarterly Geographical Journal of Amayaesh.* 3(8):21-54..

24. Zeaiean Firouzabadi, P., Valikhani, A.R., Ghanavati, E.(2010). Coastal land form and high/low tide mapping using remote sensing,GIS and GPS technologies in Coastal Regulation Zone(CRZ) (Text in Persian): Bosher area. Spatial Planning (Modares Human Sciences). 14(1 (65)):213-234.

25. Alimohammadi, A., Zeaiean Firouzabadi, P., Matkan, A.A., Jahromi M.N.(2010). IRS and MODIS image fusion for enhancement of land use and land cover classification accuracy(Text in Persian). *Journal of Applied Researches in Geographical Sciences*. 8(11):171-190.

26. Farajzadeh, M., Khorani, A., Alijani, B., and Zeaiean Firouzabadi, P. (2011). Assessment of the Effect of Climatic Factors on the Growth of Dense Pastures of Iran, Using AVHRR Images(Text in Persian). *Physical Geography Research Quarterly*, 75,pp.3-14.

27. Shoja Araghi, M., Tavalaei, S and Parviz Ziaeian. (2011).Location Analysis Regarding Disaster Management Bases via GIS Case study: Tehran Municipality(Text in Persian).*Journal Urban - Regional Studies and Research* (No.6), 3(10), p.41.

28. Mohammad Baaghideh , Bohloul Alijani , Parviz Ziaian (2011). Evaluating the possibility of using the NDVI index to analyze and monitor droughts in Esfahan Province(Text in Persian). *Arid regions Geographic Studies*.1(4). P1.

29. P. Ziaian , H. Soleimani Moghadam , and S. Barzegar.(2011) Determining the optimum direction development of Mashhad city by using multi criteria evaluation model, RS and GIS(Text in Persian). *Geography*. 9(30). P.77.

30. Farajzadeh, M., Fathnia, A., Bazgeer, S**.,** and Zeaiean Firouzabadi, P. (2012). The analysis of the agrclimatological indices and climatic elements effect on rainfed wheat in different phonological stages in Kurdistan province(Text in Persian). *Modaress Humanities*- Volume 15, Number 4, Page 1-17 (17), September 2012.

31. Zeaiean Firouzabadi, P.,Ghanavati, E, Bayatisedaghat, Z..(2012) Impact of urban constructions weight on instability, case study (district 1 of region 2 municipality of Tehran) (Text in Persian). *Journal of Applied Research in Geographical Sciences*. 12(24): 47-63.

32. Sadeghinia A., Alijani, B., and Zeaiean Firouzabadi, P. (2013). Spatio-Temporal analysis of Tehran metropolitan heat islands using remote sensing and GIS(Text in Persian). *Geography and Environmental Hazards*- Number 4, Page 1-17.

33. Hejazizadeh Z. , Alijani B. , Zeaiean P. , Karimi M. , Rafati S.(2012). Evaluation of Satellite-based Precipitation Estimates (3B43) and Comparison with Kriging Interpolation Results(Text in Persian). *Iranian Journal of Remote Sencing & GIS*, 2012 (vol4. Issue 3).

34. Saeideh Fakhari , Fathollah Naderi , Parviz Zeyaeyan Firozabadi (2012). Investigation of the range morph dynamic changing in Damavand Yakhar glacier using RS and GIS(Text in Persian). *Iranian Journal of Environmental Geology*, 2012 (Issue 17).

35. Fahiminejad, E., Hedjazizadeh Z., Alijani B., Zeaiean Firouzabadi, P. (2013). Synoptic analysis of snow storm in Gilan Province (Feb. 2005). (Text in Persian) *Geography and Regional Development*- Number 19, Page 281-302.

36. Sasanpour, F., Parviz Zeaiean Firouzabadi and Bahadori M. (2013). Study on the relationship between land use/ land cover and urban heat islands of Tehran(Text in Persian). Quarterly *Geography(39)* , Pp257.

37. Mohammad Sharifikia, Parviz Zeaiean Firouzabadi, Marzih chaji. (2013). Backscatter coefficient execution and analysis over the temporal radar double polarization signal (VV and HH) for wheat crop monitoring(Text in Persian). *Journal of Applied Research in Geographical Sciences*. 13(29): pages:1-7.

38. Zahra Hejazizadeh , Parviz Ziaeian and Alireza Shirkhani.(2013). Estimation of surface temperature using thermal-band data in the west of Tehran province and Qazvin(Text in Persian). *Quarterly Geography(38)* , P39.

39. Ghanavati, E, Karam, A., Parviz Zeaiean Firouzabadi, Mansourian S.E., Beheshti J. Ebrahim. (2013). Comparison between FAO-Iranian land evaluation model and geomorphologic parametric model for irrigated crop land suitability estimation(Text in Persian). *Quantitative geomorphological researches*. Vol.4.

40. Karam, Amir. Parviz Zeaieanfirouzabdi, Naemehsadat Mohaselhamedani. ( 2013). Study on the main factors causing Abarkoh plain sink holes and risk map creation for sinkhole suitable areas(Text in Persian). Geographical Researches on Deserts Regions. Vol.1.No.1.

41. Parviz Zeaieanfirouzabdi, Hamidreza Talkhabi, Laila Hasankhani. (2013) Change detection of Mighan desert basin using ETM+, TM, MSS images and climate data in the period of 1973 to 2011. (Text in Persian). *Journal of Applied Research in Geographical Sciences*. 13(31): pp173-189.

42. Zahra Hejazizadeh, Mostafa Karimi, Parviz Ziaeianfirouzabadi, Somayeh Rafati. (2013). Study on the Mesoscale Convective Systems (MCSs) using IR brightness temperature images over southwest of Iran(Text in Persian). *Applied Research in Geographical Sciences*. 14(32): pp45-69.

43. Riyahi V., Tavalaei, S.P. Ziaeian, A. Abdi , A. Azizdoust. (2014). Determination of Optimum Location Regarding Fire Station in Rural Settlements of Bookan. *Geography*,12(41) Page 179

44. Khoorani, A., M. Farajzadeh, S. Bazgeer and P. Zeaeian. (2014). A statistical approach for estimating wheat yield using bootstrap resampling for rain-fed farming: a case study of Kurdistan province, iran. *Bulg. J. Agric. Sci*., 20: 267-274.

45. Sadidi, J., Saeedi, R., Torahi, A. and Firuzabadi, P.Z. (2014) Determining the Optimal Algorithm to Locate the Best Place for Earthquake Refugee Camps: A Case Study for Tehran, Iran. Po s i t i o n i n g , 5, 97-106. http://dx.doi.org/10.4236/pos.2014.54012.

46. Mohammad Lotfi , Bohluol Alijani , Parviz Zeaieanfirouzabadi.(2015). Analyzing the effects of urbanization on the temperature trends in the northeast of Iran (Text in Persian). *Applied Research in Geographical Sciences*. 14(35) . Pages. 175-196.

47. Somayeh Naserpour, Bohloul Alijani, Parviz Zeaieans. (2015). The Source of Dust Storms in South West Iran using satellite images and weather maps (Text in Persian). *Physical Geography Research Quarterly. 47(91). Pages 21-36.*

48. Zahra Hejazizadeh , Parviz Zeaiean , Mostafa Karimi and Somayeh Rafati.(2015). Analysis of Spatial and Temporal Patterns of Convective Systems With Precipitation of More Than 10mm (Text in Persian). *Geography and Development Iranian Journal*, 13(39). Pages 93-106.

49. Farzane Sasanpoor, Mohammad Soleimani, Parviz Ziaeian, Zahra Delfan Azar.(2015). Position of neighborhood in city sustainable development (Case study: neighborhoods of region NO 10 of Tehran) (Text in Persian). *Human Geography Research Quarterly* Pages 159-176.

50. Javad Sadidi*, Maryam Talebzadeh, Hani Rezaian and Parviz Zeaiean Firouzabadi. (2015). Designing 3D Semantic Model in LOD4 to Simulate Building Utility Network. *Indian Journal of Science and Technology*, Vol 8(16), 58276.

## Proceedings

1. Zeaiean Firouzabadi, P., Krishnamoorthy, R., Ramachandran, S. and Udayakumar, C. (1995). Application of Fuzzy Technique for Mangrove Area Classification using IRS Data. Proceedings of the National conference on Neural Network and Fuzzy Systems, School of computer sciences and engineering, Anna University, Madras, India, 600 025 pp254-260.

2. Zeaiean Firouzabadi, P., Krishnamoorthy, R., Ramachandran, S. and Sundaram, A.(1995). Application of Fuzzy Technique for Urban Land Cover Classification using Remote Sensing Satellite Data. Proceedings of the First International conference on Space Technology and Developing Countries, Tehran, I.R. Iran, STC-95-144, pp1-7.

3. Zeaiean Firouzabadi, P., Krishnamoorthy, R., Rajmohan, N.and S. Ramachandran, (1996). Remote Sensing: An Effective Tool for Monitoring Suspended Sediment Particles in Harbour Waters. Proceedings of the Second International conference on Coasts, Ports, and Marine Structures, ICOPMAS, Tehran Iran, pp99-105.

4. Proceedings of the “INDO-US Symposium-Workshop on Remote Sensing and Its Applications” held on 6-9 Oct.1996 at IIT Bombay entitled “Spectral Reflectance of Harbour Waters in the Visible and Near Infrared Frequencies.”

5. Proceedings of the “INDO-US Symposium-Workshop on Remote Sensing and Its Applications” held on 6-9 Oct.1996 at IIT Bombay entitled “Comparison of Optical and Microwave and Suitable Techniques for Mangrove Mapping and Inventory”.

6. Zeaiean Firouzabadi, P. and Ramachandran S.(2000).Change information visualization using fuzzy logic. Proceedings of the 22nd Urban data management symposium,Technological University of Delft, Delft, The Netherlands, GIS Technology II: Geomatics and Modelling, v77-v86.

7. Zeaiean Firouzabadi, P. (2001).Performance Evaluation of Supervised Classification of Remotely Sensed Data for Crop Acreage Estimation Proceedings of the International Geo-science and Remote Sensing symposium (IGARSS2001), University of New South Wales, Sydney, Australia.

8. Zeaiean Firouzabadi, P. and Ramachandran S.(2001).Urban change detection using remote sensing data. Proceedings of the International conference on Remote Sensing, GIS and GPS (ICORG2001), Jevaher lahl Nehru Technical University, Hyderabad, India.Vol.1, pp464-469.

9. Zeaiean Firouzabadi, P. and Ramachandran S.(2001).Shore line change detection using remote sensing data. Proceedings of 5th International Pacific Ocean Remote sensing Conference (PORSEC2000) National Institute of Oceanography, GOA India. Vol.2, pp.706-709.

10. Zeaiean Firouzabadi, P. and Ghanavati, E. (2002). Digital Approaches For Change Detection In Urban Environment. Proceedings of the 11th Australasian Remote Sensing and Photogrammetry Conference BRISBANE, QUEENSLAND, AUSTRALIA. pp.592-597.

11. Zeaiean Firouzabadi, P. and Ramachandran S.(2002). Change information extraction through image processing techniques. Proceedings of the SPIE conference on Remote Sensing, Crete, Greece, Vol. 4886,pp528-533.

12. Saroei, S., Zeaiean Firouzabadi, P. and Shams. F. (2003). Remote sensing and GIS application in the field of agriculture in Iran. Proceedings of the International workshop on satellite imaging technology and applications, Krachi-Pakestan.

13. Zeaiean Firouzabadi, P. and Kohkan, R. (2003). The Holy City of Mashad, A Changing Environment, Proceedings of the IEEE 2003 International Geoscience and Remote Sensing Symposium, Toulouse, France, Vol.III: 1987 – 1989.

14. Zeaiean Firouzabadi, P. and Saeed S.(2003). Land cover mapping using remote sensing and GPS technologies for Shadegan marsh, southern part of Iran. Abstracts Book, International conference on coastal and freshwater issues, Anna university, Madras India, p.47.

15. Alimohammadi, A., Rabiei, H. and Zeaiean Firouzabadi, P. (2004). A New Approach for Modeling Uncertainty in Remote Sensing Change Detection Process. Proceedings of 12th international conference on Geoinformatics, "Geoinformatics2004, Gavle, SWEDEN,pp.503-508.

16. Zeaiean Firouzabadi, P. and Davoodi A. (2004). Study on soil erosion and sedimentation in Alashtar Watershed using image processing software. Proceedings of the XXth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Istanbul-Turkey.p1115.

17. Ghanavati, E., Zeaiean Firouzabadi, P., and Khosravy S. (2004). Digital approaches for change detection in costal environment. A case study: North West of Persian gulf ( Hendijan area). Abstract book of the 30th Congress of the International Geographical Union, Glasgow UK.

18. Zeaiean Firouzabadi, P., (2004). Geographical Information System for Agricultural Management. Abstract submitted to the IEEE international geoscience and remote sensing symposium, (igarss '04), ANCHORAGE, ALASKA.

19. Mobasheri, M., Khavarian H., Zeaiean Firouzabadi, P. and Kamali G. (2005). Estimation of evapotranspiration using MODIS images and SEBAL algorithm. Geomatics conference 84, National Cartographic Center, Tehran, Iran.

20. Zeaiean Firouzabadi, P., Nazarian A. and Jangi, A.(2005). Air pollution mapping using remote sensing, GIS and statistical data for Tehran city. Proceedings of the 1st t International conference on air pollution and combustion(CAPAC2005), Middle East Technical University (METU), Ankara, Turkey.

21. Naghdizadegan Jahromi, M. and Zeaiean Firouzabadi, P. (2006). Red tide monitoring in the northern part of Oman sea using satellite data. Proceedings of the 1st national conference on environmental engineering, Tehran University.

22. Rangzan, K., Zeaiean Firouzabadi, P., Mizaei, L. and Alijani, F. (2006). Assessing Groundwater vulnerability of nitrate contamination of Varamin plain using DRASTIC in GIS environment. Proceedings of the 1st national conference on environmental engineering, Tehran University.

23. Dadashi S. and Zeaiean Firouzabadi, P.(2006). Alteration Zone Mapping using remote sensing technology. Proceedings of the 13th symposium of Society of Crystallography and Mineralogy of Iran, Shahid Bahonar Kerman University, Kerman, Iran, pp112-117.

24. Hedjazizadeh, Z. and Zeaiean Firouzabadi, P.(2006). Study on the geomorphological conditions of south Caspian basin and southern Iran basin using satellite data. Abstracts book of the 6th congress on Marine Sciences and Technologies and first congress of Hydrography. Tehran Iran.

25. Mohamadian E. and Zeaiean Firouzabadi, P. (2006). Derivation of Unit Hydrograph for Saidon river basin using empirical and GIS methods. Abstracts book of the 6th congress on Marine Sciences and Technologies and first congress of Hydrography. Tehran Iran.

26. Derakhshan, Sh., Zeaiean Firouzabadi, P. and Bakhshipour. (2006). study on performance of different flood plain site selection Models using GIS (case study:Doviraj Ilam basin. Proceedings of the 7th international river engineering conference, Shahid Jamran University, Ahvaz Iran.

27. Rangzan, K., Derakhshan Sh., Zeaiean Firouzabadi, P. and Clay, M.A. (2006). Volume and Area derivation for Karone 3 dam lake using remote sensing data and GIS. Proceedings of the 7th international river engineering conference, Shahid Jamran University, Ahvaz Iran.

28. Alimohamadi, A., Zeaiean Firouzabadi, P. and Shamsodini. (2006). The effect of pixel size difference between panchromatic and multi-spectral images on the fused image quality. Proceedings of the Geomatics conference 1385, National Cartographic Center, Tehran, Iran.

29. Dini, Gh., Shahsawari, K. and Zeaiean Firouzabadi, P. (2006). Study on the effect of suitable land use in reduction of flooding within the Taleghan subbasin usin GIS. Proceedings of the Geomatics conference 1385, National Cartographic Center, Tehran, Iran.

30. Shojaeyan, A., Rangzan K. and Zeaiean Firouzabadi, P. (2006). Introducing a new model for land use change detection using remotely sensed images. Proceedings of the Geomatics conference 1385, National Cartographic Center, Tehran, Iran.

31. Dini, Gh., Zeaiean Firouzabadi, P. and Farajzadeh M. (2006).Study on the snow covered areas using MODIS and AVHRR images". Proceedings of the Geomatics conference 1385, National Cartographic Center, Tehran, Iran.

32. Rangzan, K., Derakhshan Sh., Zeaiean Firouzabadi, P. and Clay M.A. (2006). " Estimation of morphometric and climatological parameters using GIS and remote sensing-case study: Karone 3 dam lake Proceedings of the national conference on irrigation and drainage networks, Shahid Jamran University, Ahvaz Iran.

33. Zeaiean Firouzabadi, P., Hedjazizadeh, Z. and Bakhshandeh Nosrat A. (2006). Assessing capabilities of remote sensing technology for the geomorphological studies". Abstract book of the International Geographical Union, Brisbane Conference Regional Responses to Global Changes a View from the Antipodes, Brisbane Australia.

34. Mousavi, A. and Zeaiean Firouzabadi, P. (2006). Flood Prone Areas Simulating Using Remote Sensing Data and Cellular Automata Model (Case Study : Talar River Basin-Iran)". Abstract submitted to the joint 27th Canadian Remote Sensing Symposium and IGARSS 2006, Denver, Colorado.

35. Zeaiean Firouzabadi, P., and Javad sadidy. (2006). Paddy rice mapping of the Caspian Sea coast using microwave and optical remotely sensed data. Proc. of SPIE Vol. 6359 63591A-2.

36. Zeaiean Firouzabadi, P., Ranjbar, H. and Madanian., S. (2006). GIS for Mining Management. Abstract submitted to the International conference on space technology and geo-informatics. Thailand.

37. Alijani, B., Zeaiean Firouzabadi, P., Baaghideh, M. (2006). Drought monitoring in Isfahan province using NOAA/AVHRR remote sensing images and NDVI and VCI. Proceedings of the first disaster management conference, Tehran University, Iran.

38. Mobasheri, M.R., Jokar J. and Zeaiean Firouzabadi, P. (2007). Sugarcane water stress detection using TERRA/ASTER satellite images. Proceedings of the Geomatics 86 conference, National Cartographic Center, Tehran, Iran.

39. Shamsoddini, A., Alimohamadi A. Zeaiean Firouzabadi, P. (2007). Comparisons of different fused images derived using visual index. Proceedings of the Geomatics 86 conference, National Cartographic Center, Tehran, Iran.

40. Rokni, B., Zeaiean Firouzabadi, P. and Farajzadeh M. (2007). Accuracy Assessment of Digital elevation Model using ASTER images. Proceedings of the Geomatics 86 conference, National Cartographic Center, Tehran, Iran.

41. Sadidy, J., Zeaiean Firouzabadi, P. and Entezari, A. (2007). The Use of Radarsat and Landsat Image Fusion with Different Image Fusion Algorithms and Different Supervised Classification Methods for increasing Land use Map Accuracy-Case Study: Sari plain – Iran. Proceedings of 5th International symposium on mobile mapping technology, Padua Italy.

42. Zeaiean Firouzabadi P. and M.A.Sadeghi, M.A. (2007). Development of Geo-data base for Sialk cultural heritage site. Presented in the first Cultural and Art Conference of Sialk: the old national Identity, Kashan Iran.

43. Adeli M., Matkan, A.A., Zeaiean Firouzabadi, P. and Pourali, H. (2007). Site selection for Gorgan City fire stations using GIS", proceedings of the first Conference of Urban GIS, Shomal University, Amol, Iran.

44. Zeaiean Firouzabadi, P., Saroei, S. and keyvan keshavarz, K. (2007). Study on the flooded areas in Gorgan province, north eastern part of Iran using remote sensing GIS and GPS technologies. Abstract submitted to the 2nd International Conference of GIS/RS in Hydrology, Water Resources and Environment, China.

45. Matkan, A.A., Zeaiean Firouzabadi, P., Ashurlu, D. and Dadashi, S. (2007). Snow Cover Mapping Using Remote Sensing Data (Case Study Of Karaj And Latian Basins, Iran). Abstract book of the third international conference "Earth from space - The most effective solutions", Moscow, Russia.

46. Yazdanpanah, H. Zeaiean Firouzabadi, P., and Soleimanitabar, M. (2008). Weather-based Apple fire blight risk map generation using GIS (Case study: east Azerbaijan province, Iran), proceedings of the 11th annual international; conference and exhibition on geospatial information, technology and application. MAP India 2008, Uttar Pradesh, India.

47. Dadashi, S., Matkan, A.A., Zeaiean Firouzabadi, P., and Ashorlo, D. (2008). Evaluation Pixel-base and Sub-pixel Methods For Snow Cover Studying In Regional Scale. abstract book of the 65thd Annual Eastern Snow Conference held in Lake Morey Resort Fairlee, Vermont, USA.

48. Dini, Gh.R., Amini, M., P. Zeaiean Firouzabadi, P., and Mousavi, S.R. (2008). GIS–Based Site Selection for Solid Waste Landfill Using Fuzzy Logic Case Study: Sari City, Iran. Proceedings of the Queensland Spatial Conference, Gold coast.

49. Matkan, A.A., Zeaiean Firouzabadi, P., Ashorlo, D. and Dadashi, S., (2008). Study on the snow covered area in Central Alborz using Modis images and sub-pixel algorithm proceedings of the 1st International Conference on the Caspian Region, University of Mazanadaran- Babolsar- Iran.

50. Shakiba, A., Zeaiean Firouzabadi, P., Matkan, A.A. and Fathibaniardalan, A.A. (2008). Suitable site selection for flood areas using RS and GIS-case study: Varamin plain . proceedings of the 3rd Iran water resources Management Conference Civil engineering Dept. Tabriz University.

51. Fahiminejad, E., Hedjazizadeh, Z., Alijani, B. and Zeaiean Firouzabadi, P. (2008). Synoptic analysis of cyclonic snow(Feb. 2005) in Gilan province. Proceedings of the 3rd international conference on Comprehensive disaster management, Tehran.

52. Ghelichkhani K., Matkan, A.A., Zeaiean Firouzabadi, P. and Shakiba, A. (2008). GIS design and development with the capability of tourism information dissemination-case study: Gom city. Proceedings of the Geomatics conference 1387, National Cartographic Center, Tehran, Iran.

53. Matkan, A.A., Zeaiean Firouzabadi, P., Ashorlo, D. and Dadashi, S., (2008). Assessment of Global Normalized Differenced Snow Index(GNDSI) for the Local snow covered area. Proceedings of the Geomatics conference 1387, National Cartographic Center, Tehran, Iran.

54. Jahromi, M. N., Alimohammadi Sarab, A., Zeaiean Firouzabadi, P., and Matkan, A. A. (2009). IRS and MODIS image fusion for improving classification accuracy using linear mixing model. Paper presented in the Second International Conference on Geo-Information Technology for Natural Disaster Management and Rehabilitation, Rama Gardens Hotel, Bangkok, Thailand.

55. Zeaiean Firouzabadi, P. and Walikhani, A.R. (2010). Monitoring water rise in the Caspian Sea using advanced remote sensing, GIS and GPS technologies. Abstract submitted to the SAFARI Symposium on Remote Sensing & Fisheries, Abad Plaza, India.

56. Sadeghi A. Saeidi Kh., Shakiba A., Zeaiean Firouzabadi, P., and Matkan A.A.(2011). Urban physical growth modeling using urban cellular automata model. Proceedings of the Geomatics conference 1390, National Cartographic Center, Tehran, Iran.

57. Parviz Zeaiea Firouzabadi, Saroee S., Madaniyan E. (2012). Flood damage assessment using remote sensing, GIS and GPS technologies. Papers of the applied Geography Conference, Vol., 35/2012.

## Number of M.Sc. and Ph.D. students Guided/supervised

| University | Tarbiat Moallem University-Tehran | Tarbiat Modares University-Tehran | Shahid Beheshti University-Tehran | Shahid Chamran University-Ahvaz | Islamic Azad University-Tehran | Shahroud Industrial University | Total |
|---|---|---|---|---|---|---|---|
| **M.Sc.** | 50 | 16 | 11 | 3 | 2 | 1 | 83 |
| **Ph.D.** | 6 | 2 | - | - | - | - | 8 |

### Number of M.Sc. students Guided/supervised

| University | Tarbiat Moallem University-Tehran | Tarbiat Modares University-Tehran | Shahid Beheshti University-Tehran | Shahid Chamran University-Ahvaz | Islamic Azad University-Tehran | Shahroud Industrial University | Total |
|---|---|---|---|---|---|---|---|
| **No. of M.Sc. students** | 47 | 16 | 11 | 3 | 2 | 1 | 72 |

### Ph.D. candidates Guided/supervised

| Candidate name | Title of Ph.D. Thesis | University name | Year |
|---|---|---|---|
| **Yazdanpanah H.** | Agro-climatic Modelling and determination of climatic potential of east Azerbaijan province for rain fed wheat and apple in ,Iran | Tarbiat Moallem University, Tehran Iran | 2006 |
| **Baaghidah M.** | Drought monitoring in Isfahan provinces using temporal NOAA/NDVI images and GIS | Tarbiat Moallem University, Tehran Iran | 2007 |
| **Amanollah Fathnia** | Modelling Normalized Difference Vegetation Index (NDVI) based on Climatic Factors in Iran | Tarbiat Modares University, Tehran Iran | 2010 |
| **Khorani A.** | Statistical Rain fed wheat yield modelling based on agro-climatological and spectral indices in Kurdistan, Iran | Tarbiat Modares University, Tehran Iran | 2010 |
| **Shirkhani A.R.** | Estimation of surface temperature using thermal-band data in the west of Tehran province and Qazvin | Tarbiat Moallem University, Tehran Iran | 2010 |
| **Rafati S.** | Analysis of convective rainfall and their spatial-temporal distribution in south-eastern Iran using satellite images | Kharazmi University (Tarbiat Moallem University), Tehran Iran | 2013 |
| **Alireza Sadeghinia** | *Analysis of spatio- temporal structure of the urban heat island in tehran through remote sensing and geographic information system* | Kharazmi University (Tarbiat Moallem University), Tehran Iran | 2013 |
| | | | |

### Training/workshop participated

| Training course Title | Date | Place/Country |
|---|---|---|
| **Sustainable Agriculture and Geo-information system: Measuring the Immeasurable** | 24 Jan-11 Feb. 2005 | Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente - The Netherlands |
| **International School on LIDAR Technology** | 31-March-4 April 2008 | Indian Institute of Technology, Kanpur-India |

## Projects

| Organisation | Project Title | Main Task | Year |
|---|---|---|---|
| **Ministry of Agriculture, Tehran Iran** | *Study on the flooded areas of Gorgan province | Area estimation of flooded land during floods of 2001-2002 using RS,GIS and GPS | 2003 |
| **Tarbiat Moallem University** | *3D map generation for Tarbiat Moallem University campus using RS,GIS and GPS technologies | Map generation in 2d and 3D for the TMU Karaj Campus. | 2003 |
| **Tarbiat Moallem University** | *Capabilities of GIS in Rural land consolidation and Development | Use of GIS for the design and development of new rural plans | 2004 |
| **Tarbiat Moallem University** | *Study and Monitoring of drought in Isfahan province using remote sensing data and GIS | Drought monitoring using AVHR NDVI images | 2004 |
| **Provincial organisation for Mines and Industries-Kerman** | GIS Data base generation for Mines and Industrial units in kerman province | GIS interface generation for data entry, information query, Mine Unit records,… | 2003 |
| **Ministry of Mines and Industry, Kerman Provincial organisation for Mines and Industries-** | *The use of remotely sensed data, geophysical and Geological information towards Magnesium, Chromite Mineral exploration in the Sirjan-Sanandaj ophiolite Zone | Integration of different type of data and information for exploring hopeful areas of minerals under investigation | 2006 |
| **Ministry of Energy, Hormozgan Provincial organisation for water resources management** | *Drought Forecasting Using Remote Sensing and GIS Techniques on Minab Basin | statistical modelling of some climatologic variables such as temperature, evaporation, precipitation, SPI, NDVI, SST groundwater level and relative humidity in annual periode. | 2009 |
| **Ministry of Energy, Hormozgan Provincial organisation for water resources management** | *Analysing Drought Temporal Changes Using Remote Sensing and GIS Techniqueson Minab Basin | Over 12000 AVHRR NOAA images belonging 23 years (from 1984 to 2007 were inspected to select 2500 image to prepare NDVI and SST maps | 2009 |
| **Ministry of Jahad-e-Agriculture** | *Geographic information systems for Plant protection organization | Organization recognition, conceptual modeling, interface selection, standard of GIS database, information updating, quality controls, instruction for cartography, execute phase | 2010 |
| **Ministry of Health and Medical Education Kashan Medical university** | *GIS design and development for Health Centers in Kashan | Database generation for hospitals, health centers,… | 2010 |
| **Center of excellence for spatial analysis of natural disasters, Tarbiat Moallem University, Tehran Iran.** | *Monitoring shoreline change and its damages assessment using remote sensing data and GIS-case study: shoreline of Caspian sea in Miyankaleh region | Remote sensing data analysis GIS spatial analysis. | 2010 |
| **Department of Environment, Markazi province** | *Study on the potentials of eco-tourism of Haftadghole area using Remote Sensing and GIS Technologies. | Defining eco-tourisms potentials, Generating Database, Eco-tourism GIS development | 2011 |

***Principal investigator**

## Honours and awards

- M .Tech and Ph.D. Scholarship award, Ministry of culture and higher education, Iran.
- Best paper award, Geomatics conference, NCC, Iran
- Best researcher award, Geography Department, Tarbiat Moallem University, Tehran, Iran

## Professional affiliations

- Member of Center of Excellence for Spatial Analysis of Natural Disasters, Faculty of Geographical Sciences, Tarbiat Moallem University, Tehran Iran.
- Member of editorial board of Engineering Journal of Geospatial Information Technology (EJGIT) K. N. Toosi University of Technology, Faculty of Geodesy and Geomatics, Tehran Iran.
- Member of editorial board of "Iranian Journal of Remote sensing & GIS
- Member of editorial board and executive director of "Applied Research in Geographical Science" Journal of Kharazmi University (Teacher Training University).
- Member of editorial board and Ex-executive director of "Geography" Journal of Iranian Geographical Union.
- Ex-Member of editorial Committee of "Modares" Journal of Tarbiat Modares University.
- Ex- Board Member of the directories of the Iranian remote sensing and GIS society.
- Member of Strategic committee of Sialk cultural heritage site for 2 years.
- One year working as GIS consultant with the office of Statistics and Information Dept., Iranian cultural heritage, handicrafts and tourism organization.

## Capabilities

1. Defining and executing new projects in local and national and international scale using remote sensing and GIS technologies
2. Organizing different seminars, conferences etc., in the field of remote sensing and GIS
3. Training of staff of different departments in remote sensing and GIS.
4. Teaching remote sensing and GIS courses for undergraduate and graduate students.
5. Supervising and guiding students for their project works.

## Area of research worked.

1. Land use land cover change detection.
2. River/Coastal monitoring.
3. Uncertainties and modeling Uncertainties in change detection process.
4. Fuzzy logic applications.
5. Satellite image processing.
7. Agricultural crop acreage estimation.
8. Solid waste management.
9. Soil erosion study.
10. Remote Sensing and GIS application to Cultural Heritage.
11. Remote Sensing and GIS application in Geological explorations.
12. Climate studies using Remote Sensing and GIS.

**References**

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***3 November, 2012***

**To whom it my concern**

I am pleased to write in support of Dr. Parviz Zeaiean Firouzabadi. I know him since he was a student in Anna University in Madras, India between 1992-1998 .

He is very hard working, cooperative and well informed in the area of remote sensing. As far as I know, he has been involved in supervising about 12 research projects that were funded by different organizations. Dr. Zeaiean has supervised more than 50 M. S. thesis and about four Ph. D. dissertations in the area of remote sensing and spatial sciences. He has more than 15 years of teaching experience in remote sensing and spatial sciences courses.

Dr. Zeaiean is also well experienced in working with different softwares such as Geomatica, Arc Map, Arc View, Idrisi, Elvis and Envi. He has organized many workshops on teaching these soft wares. He has also good programming skills and is able working with FORTRAN, C, Basic, Easi modelling, and Matlab.

His research efforts ended up with 82 papers, out of which 26 papers are published in the known research journals. Generally speaking, his technical as well as his theoretical knowledge is a great asset. I wish him a great success in his research endeavor.

Yours truly,

Hojjatollah Ranjbar**Ph. D.**

Associate Professor, Department of Mining Engineering, Shahid Bahonar University of Kerman, Iran. h.ranjbar@uk.ac.ir

Kharazmi University

Center of Excellence for Spatial
Analysis of Environmental Hazards

**To whom it may concern**

**This is to certify**

That **Associate Professor Parviz Zeaiean Firouzabadi** is our colleague in the Faculty of Geographical Sciences. His specialty is Remote Sensing and has taught and researched here since 2000. He has published several articles and attended many national and international conferences. He is also expert in GIS and computer programming. He is now heading the department of Remote Sensing in this College.

As to my knowledge he is very successful teacher and his students are very satisfied with his classes. He is always updated and his lectures are always innovative and productive. In short, he is an academic and active person and is in fact one of the top leading teachers and researches of Remote Sensing in Iran.

**Bohloul Alijani**
Professor of Climatology and
Director of the Center of Excellence for Spatial Analysis of Environmental Hazards
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Recommendation of Dr. Parviz Zeaiean Firouzabadi

Dear Sir/Madam,

It is my privilege to write this recommendation for Dr. Parviz Zeaiean Firouzabadi, with whom I worked on different Earth observation projects in Iran in the last fifteen years. All these projects were financed by the UN or were joint efforts between the Netherlands and Iran at governmental level. Scientific research and practical implementation were equally important in them.

In the first project, Dr. Firouzabadi was my direct partner from the Ministry of Agriculture, Iran, related to the Shadegan Wetlands. It needed a complex approach in balancing the technical and social aspects of the remote sensing supported management of the scarce water resources. We were working in a larger consortium of Iranian and international organizations. Dr. Firouzabadi had a broad overview of this complex problem and he was always looking for and finding solutions for difficult issues. He harmonized remote sensing solutions with water management demands and limitations giving a real meaning to integrated water resources management. Working with him has been a pleasure.

He was also helping me in other projects in the Uromiyeh Basin, in NW Iran. This is a typical region of ecosystem change problems, with conflicts between upstream and downstream interests. Although Dr. Firouzabadi was indirectly involved in this project, as a senior staff member of the Remote Sensing Centre of the Ministry of Agriculture, his advice and experience was valuable for me.

Besides the technical and scientific aspects, working with Dr. Firouzabadi was very pleasant from the human point of view too, since he is a cheerful and encouraging partner. I can recommend him as a diligent and experienced researcher.

Sincerely,

Dr. Zoltán Vekerdy

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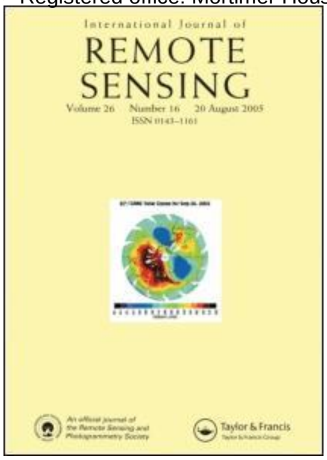


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## Monitoring geomorphologic changes using Landsat TM and ETM+ data in the Hendijan River delta, southwest Iran

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# Monitoring geomorphologic changes using Landsat TM and ETM + data in the Hendijan River delta, southwest Iran

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Beach and delta areas are dynamic physical features with changes occurring at many spatial and temporal scales due to both general and catastrophic events. Geomorphic changes such as temporal and periodic changes in riverbeds and coasts are common events in all deltaic areas. The Hendijan river basin is located in the southwest of Iran, close to the city of the Hendijan and many villages and rural settlements. Changes in various geomorphic features, such as riverbed and shoreline migration, Sebkhas, alluvial terraces, meanders and old, dry rivers over 48 years of time, were detected and identified using Landsat TM and ETM satellite data and topographic maps. Simple bands subtraction, principal component analysis (PCA) and fuzzy logic were used to identify regions that have undergone land cover change. Results of this study show that the Hendijan River channel has migrated several times over the last 48 years. Several meanders and ox-bow lakes remain as a result of migration. The shoreline has migrated over 4 km into the Persian Gulf. The resulting maps can be used in an integrated coastal zone information system as it has been proposed for the Heddijan delta.

## 1. Introduction

The coast is a component of the Earth system that the majority of humans choose to inhabit. In the United States, nearly half the population lives in one of the 451 coastal counties (Culliton et al. 1990) and similar trends exist in most other coastal nations (Douglas 2002).

Until recently, morphological coastal studies have been based on a combination of ground surveys of widely spaced transects and maps or aerial photographs. Ground surveys can provide information about the vertical or horizontal changes at single locations (Woolard and Colby 2002). Maps and aerial photos can provide useful information on long- and short-term advance or retreat of the coast, long shore movement of sediments and human impacts caused by construction. However, beach and delta areas are dynamic physical features with changes occurring at many spatial and temporal scales due to both general and catastrophic events.

Remotely sensed satellite data either optical or microwave can provides a useful source of information for studying coastal areas. Cracknell (1999) states that the coastal zone represents the last important frontier for the application of remote sensing techniques. Remote sensing is extremely valuable for studying phenomena over large spatial scales, due to the availability of wide swath satellite data (White and Asmar 1999).

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One of the most important applications of remotely sensed data is to find changes from one date to another. Many investigators like agricultural scientists, urban planners, geologists, etc., use these data to find and locate changes over a certain period of time. For most of them, it was a necessity to know where and what is the type and magnitude of the change. The basic idea behind any change detection tasks is to compare two or more images/maps or in general compare the data of the same geographical area to find and mark non-similar features on the available data. The way of doing these comparisons can be divided into two broad categories. The first way is to use conventional methods that are mainly based on the simple overlay of the raw/interpreted data and draw the boundaries of changed areas. The second method is to use advanced computer processing facilities and digital satellite remote sensing data. As far as time, cost and accuracy are concerned, the second method has advantages over the first. In the concept of change detection using satellite images, a number of different methods have been adopted. Lo (1986) classified these methods into three major approaches: (1) band ratioing; (2) transformation enhancement of multi-temporal data; (3) post-classification comparison change detection. Later on in a review article, Singh (1989) classified these techniques in ten different approaches: (1) univariate image differencing; (2) image regression; (3) image ratioing; (4) vegetation index differencing; (5) principal components analysis (PCA); post-classification comparison; (7) direct multidate classification; (8) change vector analysis; (9) background subtraction; and (10) other methods which include the Kalmogorov–Smirnov test and the use of correlation coefficients as an indicator of changes. He also described that the digital nature of most satellite data makes it amenable to computer-aided analysis. Jensen (1996) has given a useful and more generalized review of digital change detection approaches. He describes some of the

change detection algorithms that are commonly used. They are: (1) change detection using write function memory insertion (band overlay); (2) multi-date composite image change detection; (3) image algebra change detection (band differencing or ratioing); (4) post-classification comparison change detection; (5) multi-date composite image change detection using a binary mask applied to date 2. (6) multidate composite image change detection using ancillary data source as date 1; (7) manual, on-screen digitization of change; (8) spectral change vector analysis; (9) knowledge-based vision system for detecting change. They also summarized the advantages and disadvantages of all the above techniques. Change investigators have used one or a combination of the above technique to demonstrate changes over a certain period of time for a particular geographical area. In the work carried out by Howarth and Boasson (1983), the capabilities of digital enhancement for displaying change were investigated. They suggested that change enhancements could be used effectively by agencies responsible for monitoring urban development over large areas. Jensen et al. (1993) used overlay method to detect changes using SPOT panchromatic data of Par Pond in South Carolina. Byrne et al. (1980), Richards (1984), Fung and LeDrew (1987, 1988) and Bauer et al. (1994) used PCA to detect changes. Jiaju (1988) formed a three-dimensional three-date Landsat TM data set of an area between two cities of Motala and Mjolby, in the south of Sweden and applied PCA to it. Jensen et al. (1993) demonstrated the post-classification comparison method by classifying two Landsat TM images of Kittredge and Fort Moultrie, SC and then compared the resultant maps using an n6n GIS matrix. Spell et al. (1995) used the method of Multi-Date Change Detection using a Binary Change Map Applied to Date 2 to map changes over an area centred on the lower

Columbia River between Washington and Oregon. Wang et al. (1992), Cowen et al. (1991), Westmoreland and Stow (1992) and Cheng et al. (1992) used the concept of On-Screen Digitization of changes to detect changes. The Change Vector Analysis (CVA) technique has been successfully applied to monitor changes in mangrove and reef ecosystem along the coast of the Dominican Republic (Michalek et al. 1993) and for forest change mapping in the northern Idaho (Malila 1980). Gong (1993) introduced a preprocessor to automatically perform a number of digital change detection techniques including image differencing, mask creation using principal component analysis, Fuzzy supervised classification and attribute extraction.

Methods of modelling and detecting a general pattern of change associated with construction and potentially other kinds of activities in a 15 000 $km^2$ region in central Iraq using 10 Landsat TM images were presented by Carlotto (1997). He included a new nonlinear prediction technique for measuring changes between images and temporal segmentation and filtering techniques for analysing patterns of change over time. The theory of fuzzy subsets was first introduced by Zadeh in 1965. The importance of fuzzy information representation for improving remote sensing data analysis and clearly emphasizing the information loss in spectral space partition and classier training, fuzzy partition of spectral space and improvement in overall classification accuracy, with results of a case study carried out for Southwest of Hamilton city, Ontario, Canada has been discussed by Wang (1990a,b). This study has also provided valuable input to develop a fuzzy maximum likelihood classification software in the VAX operating VMS environment to analyse the Indian Remote Sensing Satellite (IRS-1A) LISS-II data of 36.25 m resolution of a mangrove land cover in Pichavaram which is located in the south-eastern coast of India (Firouzabadi et al., 1995a). Also in another attempt, Madras metropolitan urban land use/land cover areas were analysed by using the same software (Firouzabadi et al., 1995b). This study showed a better performance of fuzzy classification over maximum likelihood classification and also showed better discrimination of mixed and unmixed land use/land cover categories. Firouzabadi and Ramachandran (1997, 2000) introduced a new visualization technique base on fuzzy logic to show urban changed areas over Madras city, India. Firouzabadi and Ghanavati (2002) reported that the urban land use of Tehran was expanded with an area of 243 $km^2$ during a period of 10 years and an area of approximately 120 $km^2$ of open spaces converted to urban land use and agriculture lands have been converted to urban land use with an area of 81 $km^2$, also orchards have been changed to urban areas with an area of 40 $km^2$. Firouzabadi and Ramachandran (2000) report that a stretch of almost 10 000 m from Ennore creek down to Madras fishing harbour is an

erosional area and that the accretion sites along the Madras coast are observed to be 11490 m from an area below Madras port to Marina beach and north of Elliot beach. Alimohammadi et al. (2004) integrated the probabilistic and spatial parameters through the logistic regression modelling approach to model uncertainty of change of agriculture to urban areas.

In Iran, the river and coastal systems are one of the most important factors in the location of cities, network connections, commerce, tourism, agriculture and areas of industrial development. The Hendijan river and delta region is located along the northwest coast of the Persian Gulf. Many villages and rural settlements are situated in or around the flood plain. The city of the Hendijan, with a population greater than 100 000, is located on the delta. The consequences of geomorphic changes in this region are damage to agricultural and residential areas. In the span of 48 years, large-scale flooding has occurred three times resulting in the loss of many lives. It is therefore necessary to detect and identify the geomorphic changes in these areas. The purpose of this paper is to detect and identify the geomorphologic changes in the river and delta of the Hendijan River over a period of 48 years through simple and advanced image processing techniques such as band subtraction and fuzzy logic.

## 2. Study area

The Hendijan river basin (figure 1) is located in the southwest of Iran at the head of the Persian Gulf (30–30.75u N and 49.25–50u E). It is bounded on the north and east by the foothills of the Zagros Mountains and on the west by Mahshar port and Mosa estuary (Khor Mosa). The geological setting of the Zagros region is an early Palaeozoic to late Tertiary sedimentary basin with deposits exceeding 10 000 m in thickness, folded along a northwest–southeast trending structural belt (Perazzoli et al. 2004). The Hendijan region is mainly covered with Quaternary sediments with a low gradient (approximately 0.1%). The river drains this area and emerges in the Persian Gulf through a smooth delta.

The mean annual discharge of the river is 82 $m^3 s^{21}$ (Afshin 1994). From the plain inlet location, the slope of the riverbed decreases and in some parts takes a meandering form. In the open coast area, sandy area dominates and many related features such as marshes, barriers and sabkhas (super tidal flat formation) occupy this area.

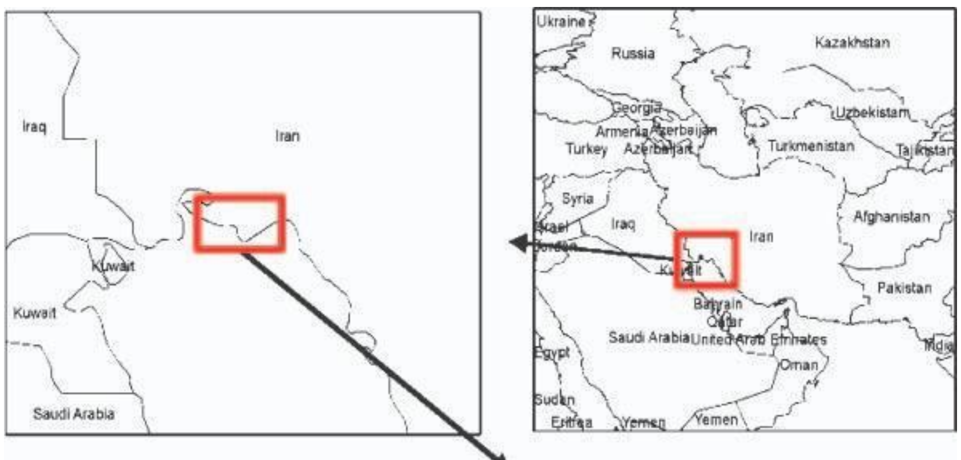


Figure 1. The location of the Hendijan River Basin in southwest Iran. Available in colour online.

## 2.1 Sea level change in Persian Gulf

The Persian Gulf is a long and shallow, almost enclosed sea bounded at the south and the west by the Arabian platform and to the north and the east by the tectonically active Zagros Mountains. It is linked to the Gulf of Oman to the southeast by the straits of Hormuz. This basin is situated in the continental shelf entirely and has no shelf edge (Shahrabi 1993). Sediment data coupled with AMS $C_{14}$ dates indicate that deposition in the Persian Gulf was controlled by the tectonic interaction between the Arabian platform and the Zagros Mountains, and by climatic, oceanographic conditions and sea level changes occurring during the latest Quaternary conditional glaciations (Uchupi et al. 1999). The latter, defining the zone of convergence between the Arabian and the Eurasian plates, represent a zone of active tectonics and uplift, whereas the Gulf and the north-westerly extension into Mesopotamia is a zone where subsidence is postulated to have been significant in recent geological time (Lambeck 1996). Today, the Tigris and Euphrates rivers flow towards the Mesopotamian lowlands and, with the Karon River, form the extensive Arvand-Rod estuary, marsh area and deltaic system at the head of Gulf. Water depths in the Gulf do not generally exceed 100 m and the average depth is only about 35 m. Thus, as has been widely recognized, much if not all of the Gulf has been above sea level during glacial time. At the peak of the last glaciations, 21 000 to 20 000 years ago, when the sea level was 120 m lower than now, the Gulf was a waterless basin and the deposition was negligible.

Comparison of AMS $C_{14}$ measurements of the late Holocene marls with the sea level curve of Fairbank (1989) indicates that the axial zone of the Gulf of Iran experienced subsidence during the Holocene. This subsidence, coupled with a rapid rise in sea level during a major glacial melt between 9500 and 8500 years ago, resulted in a global sea level rise from 250 to 228 m (Uchupi et al. 1999). Similar measurements and supporting geological data indicate that the

Mesopotamia shelf and the mouth of the Mesopotamian depression on the northwest side of the Gulf underwent both subsidence and uplift during the Cenozoic. The Arabian shelf along the Gulf southwest side appears to have experienced minor uplift during the Cenozoic.

## 3. Data and methods

Landsat TM and ETM + images acquired in 1998 and 2002 and 1 : 50 000 topographic maps produced in 1954 by the National Geographical Organization (NGO) of Iran were used in this study. The ETM + image was rectified using Image-to-Map rectification scheme with an adequate number of GCPs and with an RMS error of 0.34 pixels. The TM satellite image was co-registered to the rectified ETM + image with an RMS error of 0.3 pixels. A number of image processing techniques were applied to the data set containing all satellite data and maps. These include band subtraction, principal component analysis (PCA) and fuzzy logic. Scaled difference images derived from subtraction of six bands of Landsat TM and ETM + images of 1998 and 2002 were put gather to create a new data set. As discussed by Gong (1993), there are two problems associated with the above-mentioned traditional method of band differencing. The first problem is that different types of change information are contained in different spectral bands; thus, the use of one spectral band does not usually allow every type of change to be detected. The second problem is that once thresholding is applied to a difference image, change information occurring at smaller magnitudes will be lost. Also, noise could be included as change if its magnitude falls outside the range (Gong 1993). Therefore, the main drawback associated with the band subtraction method for change detection is that change information in difference image rarely shows all changes in a particular pixel. This is mainly due to the fact that different change information exists in different bands of satellite images. To overcome this problem, as suggested by Gong (1993), one can apply the PCA to a set of difference images. The principal component transformation multivariate statistical technique is often used for determining the underlying statistical dimension of the image data sets (Ready and Wintz 1973). Each pixel value in the PCD images is the result of a linear transformation of the difference images with the transformation coefficients determined with PCA. Because the variance in a difference image represents primarily change information and the purpose of PCA is to preserve most variances into the first few principal components, the application of PCA to difference images will result in most change information preserved in the first few PCD images (Gong 1993). In the present study and in order to identify changed and unchanged areas within the images, PCA was applied to different data sets and six new principal component difference (PCD) images were generated (figure 2). After applying PCA to the difference products of each band, the resultant principal component difference images (PCDs) were analysed. The statistical properties of each of these component images are shown in table 1.

The statistical parameters of PCD1, PCD2, PCD3 and PCD4 having histograms close to a Gaussian distribution in areas of more changes, as shown in figure 3, are used to construct a fuzzy membership function of change defined by Gong (1993).

A fuzzy membership function of change, mcj(de), can be defined as:

$$mc_j(de) = \begin{cases} 1 & 0 \le de < L_d \\ (de - ave)/(L_d - ave) & L_d \le de < ave \\ (de - ave)/(H_d - ave) & ave \le de < H_d \end{cases} \qquad (1)$$

Where mcj(de) represents the degree of pixel value de in th

1 $H_d$ v dev 255

e image PCDj belonging to a fuzzy set of change, C. $L_d$, ave, and $H_d$ are the three parameters defining the inverse triangular-shaped function (figure 4).

To apply this formula to the PCD images, the following EASI procedural program was developed and used in the modelling module of PCI GEOMATICA image processing software.

```
If (% 1.50 and % 1,20) % 251
If (% 1.520 and % 1,127) % 25((127– % 1)/(127–20))
If (% 1.5127 and % 1,230) % 25((127– % 1)/(127–230))
If (% 1.5230and % 1,255) % 251
```

Where %1 is the pixel value in first PCD image and %2 is the resultant fuzzy membership image. The generated images have a range of values between 0 and 1 for each pixel. To display these values as an eight-bit image, the values in the resultant fuzzy membership images were multiplied by 100. Through factor analysis, it was determined that the first four PCD images carry the majority of the change information. We integrated the four change membership images into one image by applying fuzzy set operation (union function) according to Zadeh (1965). The

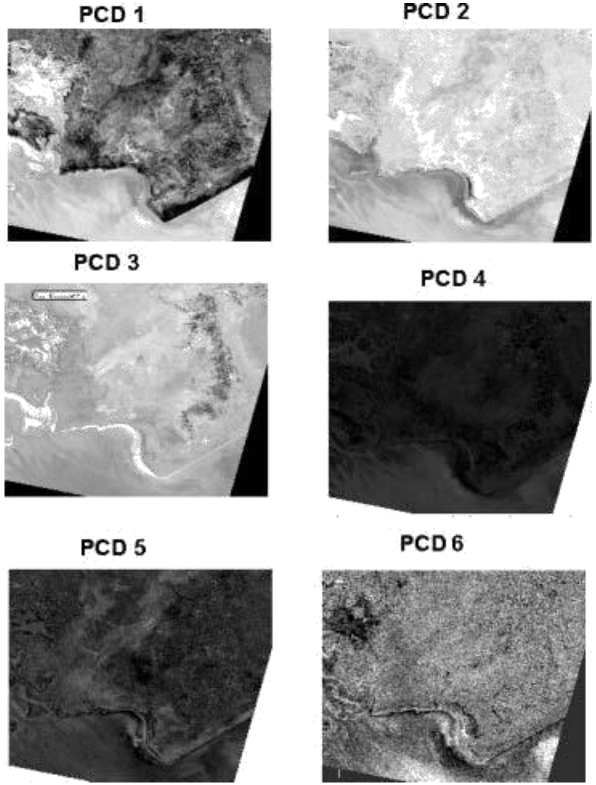



Figure 2. PCA of the difference images derived from the 1998 minus the 2002 of six Landsat TM bands.

equation is:

$$FCC1 = Max(m1, m2, m3, m4) \qquad (2)$$

where FCC1 is the fuzzy combined change image and m1–m4 are the numerical value of the membership function of the pixel in the first four PCDs. Hence, the final image that is generated by this method has a range from 0 to 100 (figure 5). In this image dark areas are less changed areas and light tones represent high changed areas. In order to better identify the sites with different magnitudes of changes, a re-classification technique was used and the magnitudes of changes were re-classified into four categories (figure 6):

Table 1. Statistical properties of the Principal Components of the six difference images (PCDs).

| PCD | Minimum | Average | Maximum | Eigenvalue | Variance |
|---|---|---|---|---|---|
| PCD1 | 20 | 127 | 230 | 2504.85 | 87.19 |
| PCD2 | 75 | 127 | 190 | 285.25 | 9.93 |
| PCD3 | 100 | 127 | 155 | 57.29 | 1.99 |
| PCD4 | 110 | 127 | 144 | 18.59 | 0.65 |
| PCD5 | 114 | 127 | 140 | 5.27 | 0.18 |
| PCD6 | 120 | 127 | 132 | 1.57 | 0.05 |

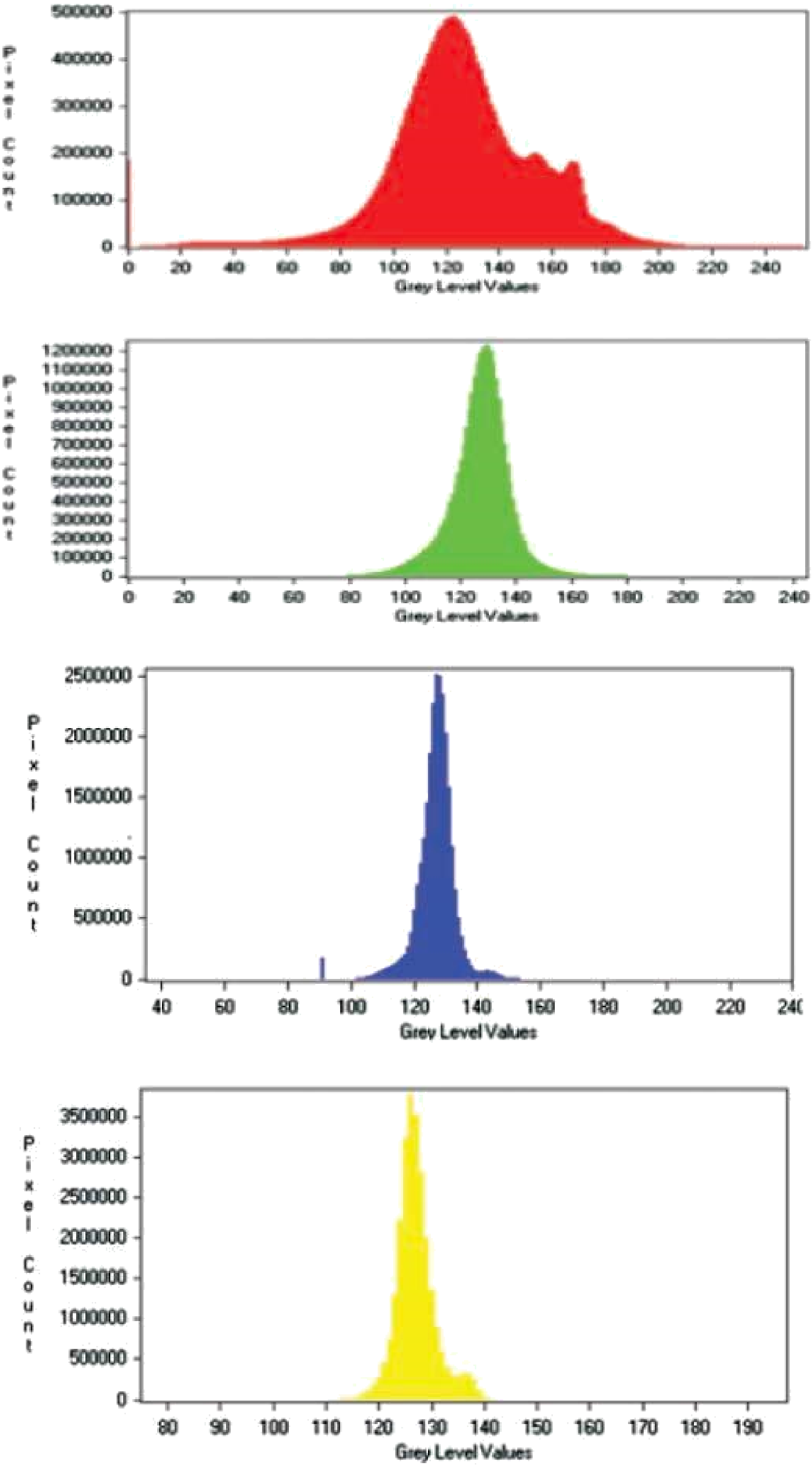



Figure 3. The histograms of PCDs 1, 2, 3 and 4.

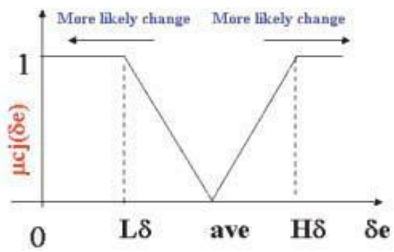



Figure 4. The inverse triangular function to construct fuzzy membership function of change.

Class 1: 00–24% low magnitudes of changes
Class 2: 25–50% medium magnitudes of changes
Class 3: 51–75% high magnitudes of changes
Class 4: 76–100% very high magnitudes of changes.

The greatest changes (red coloured areas in figure 6) have happened along the Hendijan River, areas near the coast, river mouth and Persian Gulf waters. To detect and identify river migration and the amount of sedimentation and transgression of coast towards the sea, the Landsat TM and ETM + images and the topographic maps of 1954 were overlaid on each other. From the topographic maps, the shoreline and riverbed were digitized. The locations of these features were compared to their locations in the satellite TM and ETM + images (figures 7 and 8).

By determining the location of the Hendijan River channel on the topographic maps of 1954 and satellite data of 2002, four former meanders were identified (figure 8). In this figure the red line is the river channel derived from the topographic maps of 1954 and the blue line is the river channel derived from satellite data of 2002. From ground truth investigations, it is concluded that the very low slope (about 0.1%) and fine and partially impermeable alluvial are the main causes of the Hendijan riverbed migration.

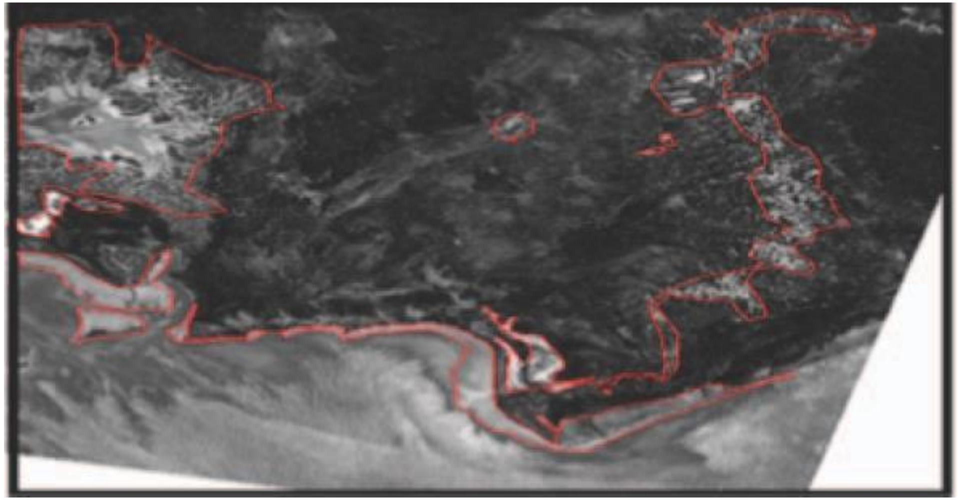


Figure 5. Fuzzy magnitude of change image (classification of changes between zero and 100%). Available in colour online.

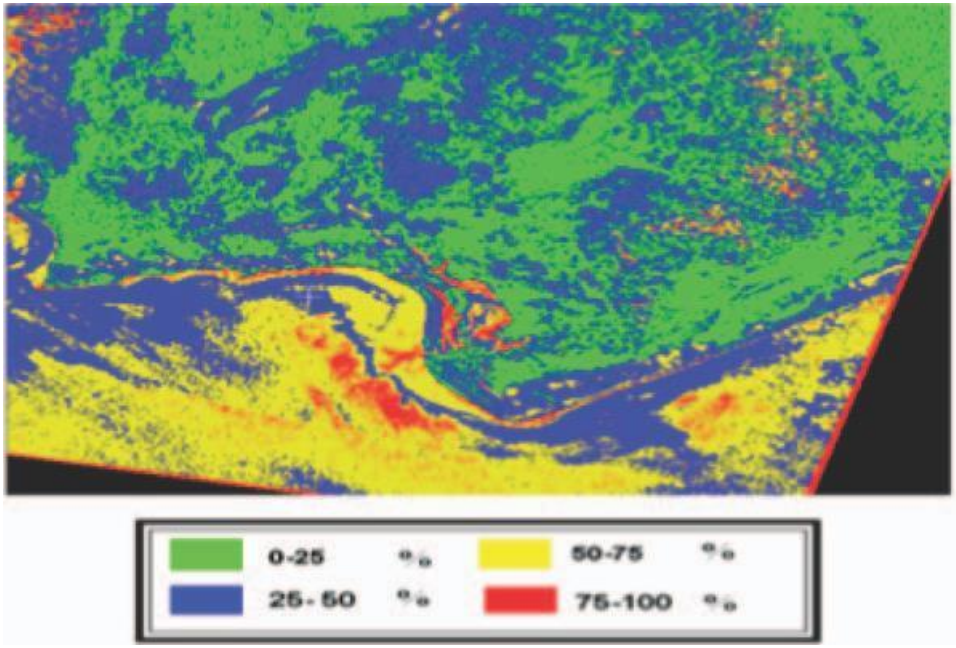



Figure 6. Re-classified image of fuzzy magnitude of change image.

A buffer zone of 1 km around the riverbed and 5 km from the shoreline was generated. All features that had been detected as undergoing changes were identified in these buffer zones and analysed. These buffer zones were overlaid on the magnitudes of change image (figure 6) to find major changed areas (figures 9 and 10).

The number of pixels and the equivalent areas of each class were calculated (table 2). The majority of changes in the shoreline buffer zone and the river channel buffer zone occurred in medium and high ranges of changes (second and third class).

Figure 7. The location of the shorelines in 1954 (green line) and in 2002 (red line).

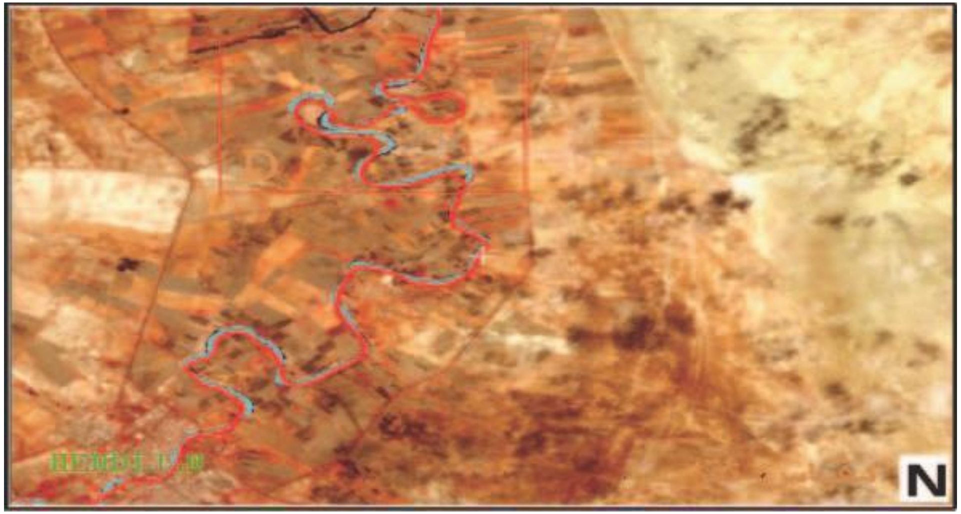
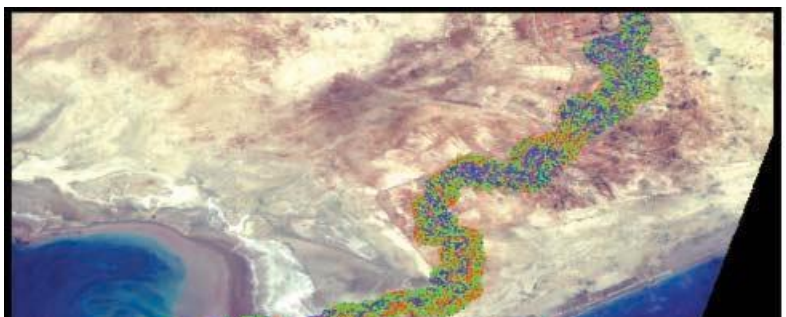



Figure 8. The migration of the Hendijan river channel between 1954 (red line) and 2002 (blue line).



nitude of change (%) image of the Hendijan river channel between 1954 and 2002.

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Figure 10. The magnitude of change (%) image of the Hendijan delta shoreline between 1954 and 2002.

Finally, the geomorphologic changed features identified from the above mentioned analyses of image data were evaluated by observations made in the field.

## 4. Results and discussion

Results of this research indicate that digital image processing is an extremely useful technique for the analysis and detection of change in coastal areas. By using Landsat images and old topographic maps, temporal and spatial changes within various magnitudes for geomorphic features such as river channels, both former and current, shoreline migration, Sebkhas, alluvial terraces, meanders and river

Table 2. The number of pixels located within each magnitude of change class.

| Magnitude of change % | Number of pixels (river) | Area of river (Hectare) | Number of pixels (shoreline) | Area of shoreline (hectare) |
|---|---|---|---|---|
| 0–24 | 20 892 | 1703 | 84 022 | 6849 |
| 25–50 | 90 916 | 7411 | 498 382 | 40 623 |
| 51–75 | 51 787 | 4221 | 262 431 | 21 391 |
| 76–100 | 16 777 | 1368 | 96 411 | 7858 |
| Sum | 180 372 | 14 702 | 941 236 | 76 721 |

were detected and identified. One former river channel, 30 km long and 300 m in width, was identified and could be used to reconstruct floods in the Hendijan River.

By overlying the topographic maps and images, it is clear that the Hendijan River channel has migrated several times over a period of 48 years. Several meanders and ox bow lakes remain as a result of these migrations. The shoreline has migrated over 4 km into the Persian Gulf, an average annual rate of 90 m. Approximately 82 $km^2$ of water has become filled with sediment. With reference to the theory of Petrov (1970), the current in the Persian Gulf flows from north of the Hornoz straight, and then enters into the Gulf along the southern coast of Iran and flows to the west. Hence, this results in a sediment movement to the west into the mouth of the Hendijan River delta.

Fuzzy logic used here also provides useful information about geomorphologic changes which have happened in this area. Images generated to show the magnitudes of changes over particular buffer zones are in support of the fact that all geomorphic features are dynamic in nature. Therefore, to study the behaviour of such features one should consider using a wide range of advanced techniques based on fuzzy logic, neural networks, genetic algorithm and cellular automata.

The resulting maps can be used in an integrated coastal zone information system as it has been proposed for Heddijan delta similar to that developed for the Netherlands (van Heuvel and Hillen 1995). The synoptic capability of remote sensing provides a useful reconnaissance tool to target more detailed field surveys in areas of rapid and/or accelerating change.

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## References


Afshin, Y., 1994, The Rivers of Iran (Iran: Ministry of Energy).

Alimohammadi, A., Rabiei, H.R. and Firouzabadi, P.Z., 2004, A new approach for modelling uncertainty in remote sensing change detection process. Proceedings of 12th International Conference on Geoinformatics, University of Gävle, pp. 503–508.

Bauer, M.E., Burk, T.E., A.R., Coppin, P.R., Lime, S.D., Walsh, T.A., Walters, D.K., Befort, W. and Heisen, D.E., 1994, Satellite inventory of Minonesota forest resources. Photogrammetric Engineering and Remote Sensing, 60, pp. 287–298.

Byrne, G.F., Crapper, P.I. and Mayo, K.K., 1980, Monitoring Land-cover change by principal component analysis of multitemporal Landsat data. Remote Sensing of Environment, 10, pp. 175–184.

Carlotto, M.J., 1997, Detection and analysis of change in remotely sensed imagery with application to wide area surveillance. IEEE Trans. On Image Processing, 6, pp. 189–202.

Cheng, T.D., Angelici, G.L., Slye, R.E. and Ma, M., 1992, Interactive Boundary Delineation of Agricultural Lands Using Graphics Workstations. Photogrammetric Engineering and Remote Sensing, 58, pp. 1439–1443.

Cowen, D.J., Jensen, J.R. and Halls, J., 1991, Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. Photogrammetric Engineering and Remote Sensing, 49, pp. 1671–1678.

Cracknell, A.P., 1999, Remote sensing techniques in estuaries and coastal zones-an update. International Journal of Remote Sensing, 19, pp. 485–495.

CULLITON, T.J., WARREN, M.A., GOODSPEED, T.R., REMER, D.G., BLACKWE LL, C.M. and McDONOUGH, J.J., III., 1990, 50 years of population change along the Nation's coasts, 1960–2010. Rockville, MD., National Oceanic and Atmospheric Administration Coastal Trends Series, 2D Report, 41 P.

DOUGLAS, J.S., 2002, The geomorphology of coastal environment Geomorphology, 48, pp. 1–6.

FAIRBANKS, R.G., 1989, A 17,000 year glacio-eustatic sea level record; influence of glacial melting rates and the Younger Dryas event and deep-ocean circulation. Nature, 342, pp. 637–642.

FIROUZABADI, P.Z., 1997, Digital approaches for change detection in urban environments using remote sensing data. PhD thesis, ANNA UNIVERSITY, MADRAS, INDIA.

FIROUZABADI, P.Z. and GHANAVATI, E., 2002, Digital approaches for change detection in urban environment. Proceedings of 11th Australasian Remote Sensing and Photogrammetry Conference, Brisbane, Australia.

FIROUZABADI, P.Z., KRISHNAMOORTHY, R., RAMACHANDRAN, S. and UDAYKUMAR, C., 1995a, Application of fuzzy technique for mangrove area classification using Indian remote sensing satellite data. Proceedings of the national conference on neural network and fuzzy systems, Anna University, Madras, India.

FIROUZABADI, P.Z., KRISHNAMOORTHY, R., RAMACHANDRAN, S. and SUNDARAM, A., 1995b, Application of Fuzzy Technique for Urban Land Cover Classification using Remote Sensing Satellite Data. Proceedings of the First International conference on Space Technology and Developing Countries, Tehran, I.R. Iran, STC-95–144, pp. 1–7.

FIROUZABADI, P.Z. and RAMACHANDRAN, S., 2000, Change information visualization using fuzzy logic. Proceedings of the 22nd Urban data management symposium held on 11–15 Sept. 2000 at Technological University of Delft, Delft, The Netherlands.

FIROUZABADI, P.Z. and RAMACHANDRAN, S., 2000, Shoreline Change Detection Using Remote Sensing Data. 5th Pacific Ocean Remote Sensing Conference (PORSEC2000) held in Goa, India.

FUNG, T. and LEDREW, E., 1987, Application of principal component analysis to change detection. Photogrammetric Engineering and Remote Sensing, 53, pp. 1649–1658.

FUNG, T. and LEDREW, E., 1988, The determination of optical threshold levels for change detection using various accuracy indices. Ph

otogrammetric Engineering and Remote Sensing, 54, pp. 1449–1454.

GONG, P., 1993, Change detection using principal components analysis and fuzzy sets theory. Canadian Journal of Remote Sensing, 19, pp. 22–29.

HOWARTH, P.J. and BOASON, E., 1983, Landsat digital enhancements for change detection in urban environments. Remote Sensing of Environment, 13, pp. 149–160.

JAIJU, L., 1988, Development of principal component analysis applied to multispectral landsat TM data. International Journal of Remote Sensing, 6, pp. 141–157.

JENSEN, J.R., NARUMALANI, S., WEATHERBEE, O. and MACKEY, H.E., 1993b, Measurement of seasonal and yearly cattail and waterlily changes using multi-date SPOT panchromatic data. Photogrammetric Engineering and Remote Sensing, 59, pp. 519–525.

JENSEN, J.R., 1996, Introductory digital image processing, a remote sensing perspective, Second edition (New Jersey: Prentice Hall).

LAMBECK, K., 1996, Shoreline reconstructions for the Persian Gulf since the last glacial maximum. Earth and Planetary Science Letters, 142, pp. 43–57.

LO, C.P., 1986, Applied remote sensing (New York: Longman Inc.).

MALILA, W.A., 1980, Change vector analysis:An approach for detecting forest changes with landsat. Proceedings, LARS Machine Processing of Remotely Sensed Data Symposium (W. Lafayette, IN: Laboratory for the Application of Remote Sensing), pp. 326–336.

MICHALEK, J.L., WANGNER, T.W., LUCZKOVICH, J.J. and STOFFLE, R.W., 1993, Multispectral change rector analysis for monitoring coastal marine environment. Photogrammetric Engineering and Remote Sensing, 59, pp. 381–384.

Perazzoli, P.A., Reyss, J.L., Fountugne, M., Haghipour, A., Hilgers, A., Kasper, H.U., Nazari, H., Preusser, F. and Rad, U., 2004, Quaternary coral-reef terraces from Kish and Qeshm Islands, Persian Gulf: new radiometric ages and tectonic implications. Quaternary International, 120, pp. 15–27.

Petrov, M., 1970, The Physical Geography of Iran (Tehran Iran: Dehkhoda Publishers).

Ready, P.J. and Wintz, P.A., 1973, Information Extraction, SNR Improvement and Data Compression in Multispectral Imagery. IEEE Trans. Common., 21, pp. 1123.

Richards, J.A., 1984, Thematic mapping from multispectral image data using the principal component transformation. Remote Sensing of Environment, 16, pp. 35–46.

Shahrabi, M., 1993, The Geology of Iran, Iranian Geological Survey.

Shi, W.Z. and Ehlers, M., 1996, determining uncertainties and their propagation in the dynamic change detection based classified remotely sensed images. International Journal of Remote Sensing, 17, pp. 2729–2741.

Singh, A., 1989, Digital change techniques using remotely sensed data. International Journal of Remote Sensing, 10, pp. 989–1003.

Spell, E.R., Kempka, R.G., Graves, K.J. and Cagney, T.P., 1995, Change detection of Pacific coast estuaries and bays using landsat thematic mapper. Presented in the Third thematic conference on remote sensing for marine coastal environments, Seattle, Washington, DC.

Uchupi, E.S., Swift, A. and Ross, D.A., 1999, Late Quaternary stratigraphy, Paleclimate and neotectonism of the Persian Gulf region. Marine Geology, 160, pp. 1–23.

Van Heuvel, T. and Hillen, R., 1995, Coastline management with GIS in the Netherlands. EARSeL Advances in Remote Sensing, 4, pp. 27–34.

Wang, F., 1990a, Fuzzy supervised classification of remote sensing images. IEEE Transactions on Geoscience and Remote Sensing, 28, pp. 194–201.

Wang, F., 1990b, Improving remote sensing image analysis through fuzzy information representation. Photogrammetric Engineering and Remote Sensing, 8, pp. 1163–1169.

Wang, J., Treitz, P.M. and Howorth, P.J., 1992, Road network detection from SPOT imagery for updating geographical information systems on the rural-urban fringe. International Journal of Geographical Information Systems, 6, pp. 141–157.

Westmoreland, S. and Stow, D.A., 1992, Category identification of changed land-use polygons in an integrated image processing geographic information system. PE&RS, 58, pp. 1593–1599.

White, K. and Asmar, H.M., 1999, Monitoring change position of coastlines using Thematic Mapper imagery, an example from the Nile Delta. Geomorphology, 29, pp. 93–105.

Woolard, J.W. and Colby, J.D., 2002, Spatial characterization, resolution, and volumetric change of coastal dunes airborne LIDAR: Cape Hatteras, North Carolina. Geomorphology, 48, pp. 269–287.

Zadeh, L.A., 1965, Fuzzy sets. Information and Control, 8, pp. 338–353.

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# CHANGE INFORMATION VISUALIZATION USING FUZZY LOGIC

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## ABSTRACT

One of the most important problems associated with most of the widely used image classification algorithms such as maximum likelihood algorithm is the information loss during different stages of the classification process. A fuzzy based supervised classification algorithm can easily overcome this problem by simply assigning a membership grade vector to each pixel to be classified. These membership grades carry most of the lost information and therefore they can be used to show how really a pixel has changed from one date to another. To do this, based on fuzzy logic, a supervised classifier has been developed in a DEC ALPHA 3000 workstation and used to classify two multitemporal near anniversary IRS-1B LISSII sub scenes covering a part of Madras (*renamed Chennai*) India. By using membership grades of each pixel, three output images were generated. One image shows the magnitude of change in membership grades of a pixel, another indicates the type of change and the last image gives information on the change in membership of a pixel with respect to the class changes. With these three images an analyst is able to get most of the change information of a particular pixel or a group of pixels.

## INTRODUCTION

One of the most important applications of remotely sensed data is to find changes from one date to another. Many investigators like agricultural scientists, urban planners, geologists, etc., use these data to find and locate changes over a certain period of time. For most of them, it is a necessity to know where and what is the type and magnitude of the change. The basic idea behind any change detection tasks is to compare two or more images/maps or in general compare the data of the same geographical area to find and mark non-similar features on the available data. The way of doing these comparisons could be divided into two broad categories. The first way is to use conventional methods that are mainly based on the simple overlay of the raw/interpreted data and draw the boundaries of changed areas. The second method is to use advanced computer processing facilities and digital satellite remote sensing data. As far as time, cost and accuracy are concerned, the second way has advantages over the first one. In the concept of change detection using satellite images, a number of different methods have been adopted. Lo (*1986*) classified these methods in three major approaches: (*1*) band rationing; (*2*) transformation enhancement of multi-temporal data; (*3*) post classification comparison change detection. Later on in a review article, Singh (*1989*) classified these techniques in ten different approaches: (*1*) univariate image differencing; (*2*) image regression; (*3*) image rationing; (*4*) vegetation index differencing; (*5*) principal components analysis (*PCA*); post classification comparison; (*7*) direct multi date classification; (*8*) change vector analysis; (*9*) background subtraction; and (*10*) other methods which include Kalmogorov-Smirnov test and the use of correlation coefficient as an indicator of change. He also described that the digital nature of most satellite data makes it amenable to computer-aided analysis. In digital analysis, although the information content of the satellite data can be fully utilised but so many factors should be considered before implementing any analysis. For example, successful remote sensing change detection requires careful attention to both (*1*) the remote sensing system and (*2*) environmental characteristics. Failure to understand the impact of the various parameters on the change detection process can lead to inaccurate results (*Dubson et al. 1995*). Jensen (*1996*) has given a useful and more generalised review of digital change detection approaches. He describes some of the change detection algorithms that are commonly used. They are:(*1*) change detection using write function memory insertion (*band overlay)* (*2*) multi date composite image change detection. (*3*) image algebra change detection (*band differencing or rationing*) (*4*) post-classification comparison change detection. (*5*) multi date composite image change detection using a binary mask applied to date 2. (*6*) multi date composite image change detection using ancillary data source as date 1. (*7*) manual, on-screen digitisation of change. (*8*) spectral change vector analysis. (*9*) Knowledge-based vision system for detecting change. He has also summarised the advantages and disadvantages of all the above techniques. Change investigators used one or a combination of the above technique to demonstrate changes over a certain period of time for a particular geographical area. In the work carried out by Howarth and Boasson (*1993*); the capabilities of digital enhancement for displaying change were investigated. They suggested that change enhancements could be used effectively by agencies responsible for monitoring urban development over large areas. Jensen (*1993b*) used overlay method to detect changes using SPOT panchromatic data of Par Pond in South Carolina. Byrne et. al. (*1980*), Richards (*1984*), Fung and LeDrew (*1987, 1988*) and Bauer et. al., (*1994*) used PCA to detect changes. Jiaju (*1988*) formed a three-dimensional three-date Landsat TM data set of an area between two cities of Motala and Mjolby, in the south of Sweden and applied PCA to it. Jensen et. al. (*1993a*) demonstrated the Post classification comparison method by classifying two Landsat TM images of Kittredge and Fort Moultrie, S.C. and then compared the resultant maps using an $n \times n$ GIS matrix. Spell et. al. (*1995*) used the method of Multi-Date Change Detection using a Binary Change Map Applied to Date 2 to map changes over an area centred on the lower Columbia River between Washington and Oregon. Wang et. al. (*1992*), Cowen et. al. (*1991*), Westmoreland and Stow (*1992*) and Cheng et. al. (*1992*) used the concept of On-Screen Digitisation of changes to detect changes. The Change Vector Analysis Technique has been successfully applied to monitor changes in mangrove and reef ecosystem along the coast of the Dominican Republic (*Michalek et. al. 1993*) and for forest change mapping in the northern Idaho (*Malila, 1980*). Gong (*1993*) introduced a pre-processor to automatically perform a number of digital change detection techniques including image differencing, mask creation using principal component analysis, Fuzzy supervised classification and attribute extraction. Methods of modelling and detecting a general pattern of change associated with construction and potentially other kinds of activities in a 15 000 $km^2$ region in central Iraq using ten Landsat TM images were presented by Carlotto (*1997*). He included a new non-linear prediction technique for measuring changes between images and temporal segmentation and filtering techniques for analysing patterns of change over time.

**F**UZZY SUPERVISED CLASSIFICATION ALGORITHM

Zadeh first introduced the theory of fuzzy subsets in 1965. The importance of fuzzy information representation for improving remote sensing data analysis and clearly emphasising the information loss in spectral space partition and classier training, fuzzy partition of spectral space and improvement in overall classification accuracy, with results of a case study carried out for Southwest of Hamilton city, Ontario, Canada has been discussed by Wang (*1990a*). This study has also provided valuable input to develop a fuzzy maximum likelihood classification software in the VAX operating VMS environment to analyse the Indian Remote Sensing Satellite (*IRS-1A*) LISS-II data of 36.25 meter resolution of a mangrove land cover in Pichavaram which is located in the south-eastern coast of India (*Parviz Zeaiean Firouzabadi et. al., 1995a*). Also in another attempt, Madras metropolitan city urban land use/land cover areas were analysed by using the same software (*Parviz Zeaiean Firouzabadi et. al., 1995b*). This study showed a better performance of fuzzy classification over maximum likelihood classification and also showed better discrimination of mixed and unmixed land use/land cover categories. Fuzzy set theory as an alternative representation method is based on partial and multiple membership. According to the fuzzy set theory an element can partially belong to a set and at the same time it can be a member of another set with a different membership grade. In this case, the loss of information that occurs in most of the classification techniques may not occur and more information about the object will be provided.

When working with real remote sensor data, the actual fuzzy partition of spectral space is a family of fuzzy sets, *F1, F2, ..., Fm* on the universe X such that for every x which is an element of X (*Wang, 1990b*):

$$0 \leq f_{Fi}(x) \leq 1 \qquad \sum_{x \in X} f_{Fi}(x) > 0 \qquad \sum_{i=1}^{m} f_{Fi}(x) = 1 \geq$$

where *F1, F2, ..., Fm* represents the spectral classes, X represents all pixels in the data set, $m$ is the number of classes trained upon, $x$ is a pixel measurement vector, and $f_{Fi}(x)$ is the membership function of the fuzzy set $Fi$ ( $1 \leq i \leq m$ ).
The fuzzy partition may be recorded in a fuzzy partition matrix:

$$\left| \begin{vmatrix} f_{F1}(x1) & f_{F1}(x2) & \dots & f_{F1}(xn) \\ f_{F2}(x1) & f_{F2}(x2) & \dots & f_{F2}(xn) \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ f_{Fm}(x1) & f_{Fm}(x2) & \dots & f_{Fm}(xn) \end{vmatrix} \right|$$

where $n$ is the number of pixels and $xi$ is the $i$th pixel's measurement vector ($1 \leq i \leq m$) .

The following is the definition of the membership function given by Wang (*1990b*) for cover class c, which is based on maximum likelihood classification algorithm with fuzzy mean $\mu^*$ and fuzzy covariance matrix $\sum^*$ replacing the conventional mean and covariance matrix,

$$f_c(x) = \frac{P_c^*(x)}{\sum_{i=1}^{m} P_i^*(x)}$$

Where

$$P_i^*(x) = \frac{\exp -0.5\left[ (x - \mu^*_i)^T \Sigma_i^{*\,-1} (x - \mu^*_i) \right]}{(2\pi)^{N/2} \, |\Sigma_i^*|^{1/2}}$$

N is the ~~dimension of the pixel vectors, *m* is the~~ number of predefined classes, and $\mu^*_i$ and $\Sigma_i^*$ are the fuzzy mean and covariance matrix of class *i*, and $1 \leq i \leq m$. Calculation of $\mu^*_c$ and $\Sigma_c^*$ are given by Wang (*1990a*). Considering the above concept, a fuzzy maximum likelihood classifier was developed in the VAX operating VMS environment and then transferred to a DEC ALPHA UNIX based workstation. Since the space taken by the fuzzy membership grades of pixels is large, only a sub scence of 330 × 190 scanline-pixel was extracted from the original data sets (*Figure 1*). The extracted sub scene covers an area where the major land use/ land cover are settlement, dense and sparse vegetation, settlement with vegetation, sand, sea water and river. The sub scenes were trained for nine classes and classified separately using fuzzy classifier. Two outputs of this classifier were used to generate new change maps in which one can get more information on type, direction and magnitude of the change. The way of how these maps were generated is given in the next section.

*Figure 1: FCC of study area (Madras City and its environments).*

CHANGE MAP CREATION USING MEMBERSHIP GRADES OF PIXELS

For the creation and visualisation of change, the following two different strategies were adopted:

**Classification using membership grades and change map creation based on the results of classification outputs**

After calculation of membership grades for all the classes, a pixel can be classified into the class that has maximum membership grade (*hardening the membership grade vectors*). The same can be done to the second image and then the resultant outputs of the two dates can be compared. Using the following formula can generate a coded output,

$$\mathrm{CHM}(i, j) = (\mathrm{OUT2}(i, j) \times 10) + \mathrm{OUT1}(i, j)$$

where $i$ , $j$ are the x and y location of the pixel and OUT2( $i$ , $j$ ), OUT1( $i$ , $j$ )are the class values in the output of the date 1 and date 2 respectively and CHM( $i$ , $j$ )is the resultant change image. For example, if a pixel in date 1 is classified into class 2 and the same pixel in date 2 is classified into class 3, in the change image number 23 represents change from class 2 to class 3. Numbers 11, 22, 33 or 44 in the output image indicate no changed pixels. This image just shows type of change and no matter how a pixel has changed from date one to date two.

**Change map creation by using fuzzy membership grades of pixels**

The logic given below explains how one can use the fuzzy membership grades of a pixel to bring out change information in that particular pixel. The logic is based on the fact hypothesis that any change in class membership grades of a pixel is due to the change in spectral characteristics of that particular pixel. The membership grades can be compared in different ways to create a number of change information thematic maps. During image classification based on fuzzy logic with *m* number of classes, for a given pixel, A, in date 1 image, there can be *m* possible fuzzy membership grades. The same number of membership grades is expected for the same pixel in date 2 image. In a vector form, they can be expressed as:

$$f(x_A) = [\, f_1(x_A),\; f_2(x_A), \ldots, f_m(x_A)] \qquad f'(x_A) = [\, f'_1(x_A), f'_2(x_A), \ldots, f'_m(x_A)]$$

where $f_i(x_A)$ and $f'_i(x_A)$ are the fuzzy membership grades of pixel A for class $i$ ($1 \le i \le m$) in date 1 and date 2 respectively. $f(x_A)$ and $f'(x_A)$ are the fuzzy membership grade vectors for pixel A in date 1 and date 2 respectively. If there is no real change between date 1 and date 2, then all the similar 1st, 2nd, … ,$m$th elements of the vectors $f(x_A)$ and $f'(x_A)$ should be the same. On the other hand if there is a little change between these two dates, then some or all of these elements might not be the same. In this case some of the membership grades are expected to increase, decrease or remain constant. As an example, consider $f(x_A)$ = [0.0, 0.1, 0.2, 0.0, 0.7) and $f'(x_A)$ = ( 0.1, 0.0, 0.3, 0.0, 0.6) being the fuzzy membership grade vectors for pixel A in date 1 and date 2 respectively. The change information that can be retrieved by comparison between these two vectors is as follows:

Pixel A has partially changed from date 1 to 2 for the classes 1, 2, 3 and 5 ( *the membership grades of classes 2 and 5 are reduced and membership grades of classes 1 and 3 are increased*) and these pixels show no changes for class number 4. Here if we use their classified outputs for comparison, we do not observe any change for that particular pixel. But this will not be true. In real world this pixel has partially changed (*look at the membership grades*) and this change could not be detected by the user while using conventional classifiers.

As mentioned early in this section, one can use these membership grades to detect and visualise changes. Here we explain two algorithms one to visualise the magnitude and one to show type and direction of change over the study area. At First, just by using corresponding membership grades one can find the distance between the membership grade vectors based upon the following formula:

$$\text{DISPIX}(A) = [(f_1(x_A) - f'_1(x_A))^2 + (f_2(x_A) - f'_2(x_A))^2 + \ldots + (f_m(x_A) - f'_m(x_A))^2]^{1/2}$$

After calculating these distances for all the pixels, the resultant DISPIX' (*ranging from 0 to 2*) are multiplied with a constant of 127.5 for better visualisation of the resultant image. This image which is called "fuzzy membership grades magnitude change image" can easily show the areas where we had no, a little, more or maximum changes. In this image, number 0 indicates no change and number 255 shows the maximum change that has happened in the time interval between date 1 and 2. Figure 2 shows the resultant image in which the changed areas are shown in white colour and unchanged areas in black.

*Figure 2: Fuzzy membership grades magnitude change image.*

In the second method, from the membership grade vectors of the date 1 and date 2 (i.e., $f(x_A)$ and $f'(x_A)$), the highest membership grade values were selected and compared. In this case there would be three possibilities for the highest membership grade. It may increase/decrease or remain constant. On the other hand, these membership grades may or may not belong to the similar classes in the date 1 and date 2. Together, six possibilities can be encountered for a pixel changed or not changed from date 1 to date 2. These possibilities can be decoded in the form of a final change theme map. Table 1 shows these possibilities and their arbitrary code numbers. Figure 3 shows the resultant coded image for the study area.

Table 1. Arbitrary code numbers for the possibilities of the membership grade of a pixel for different dates.

| Code number | Possibility |
|---|---|
| 40 | pixel's class is not changed but its membership grade is reduced |
| 80 | pixel's class is not changed and its membership grade is not changed |
| 120 | pixel's class is not changed but its membership grade is increased |
| 160 | pixel's class is changed but its membership grade is reduced |
| 200 | pixel's class is changed but its membership grade is not changed |
| 240 | pixel's class is changed but its membership grade is increased |

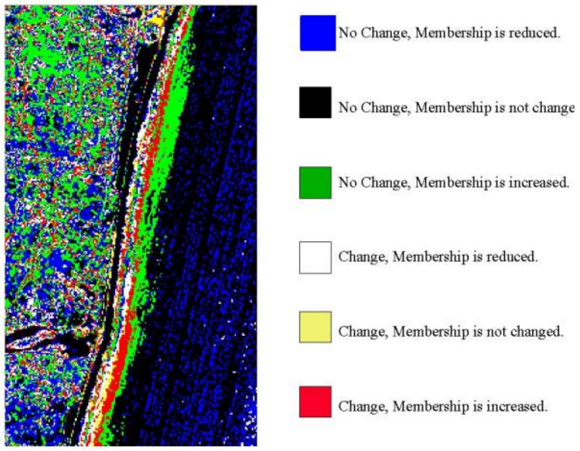


*Figure 3: Out put image shows changed and unchanged classes and their fuzzy membership status.*

The fuzzy membership grade comparison and calculation of distance between membership grade vectors has been carried out using a FORTRAN program which accepts input parameters (*fuzzy membership grade vectors and desired code numbers*). This program can also provide statistical information on the number of changed/unchanged pixels in every output image. The outputs of this program can then be transferred to an image processing software and displayed for further analysis.

A false colour composite of three images created using fuzzy membership grade can provide useful information on pixel by pixel basis as well as global coverage of an area.

**CONCLUSION**

In this study, we demonstrated the usefulness of fuzzy membership grades of each pixel for displaying changes over an urban area. Fuzzy membership grades are used to show type, magnitude and direction of changes. Lost information during most of the classification stages can easily be retrieved and displayed through fuzzy membership grades. But computationally, any analysis on membership grades is a time consuming task. To avoid more computation, one can optionally select one or few membership grades to make a comparison by the computer program. In such a case, some information will be lost.

In the case of fuzzy membership grades magnitude change image, all the membership is included in the calculation. So, information will not be lost at any cost. In addition to that, the output shows real changes for every pixel.

## REFERENCES


*Bauer, M.E., Burk, T.E., A.R., Coppin, P.R., Lime, S.D., Walsh, T.A., Walters, D.K., Befort, W. and Heisen, D.E. (1994)*: Satellite inventory of Minonesota forest resources, PE&RS, Vol .60 (3), pp. 287-298.

*Byrne, G.F., Crapper, P.I. and Mayo, K.K. (1980)*: Monitoring Land-cover change by principal component analysis of multitemporal Landsat data, Remote Sensing of Environment, Vol. 10, pp 175-184.

*Carlotto, M.J. (1997*): Detection and analysis of change in remotely sensed imagery with application to wide area surveillance, IEEE Trans. On Image Processing, Vol.6 pp 189-202.

*Cheng, T.D., G.L. Angelici, R.E.Slye and M.Ma., (1992)*: Interactive Boundary Delineation of Agricultural Lands Using Graphics Workstations, PE&RS, Vol. 58 (10): 1439-1443.

*Cowen, D.J., Jensen, J.R. and Halls, J. (1991)*: Assessing landsat classification accuracy using discrete multivariate analysis statistical techniques, PE&RS, Vol. 49, pp 1671-1678.

*Dobson E.J. (1993)*: Commentary:A Conceptual framework for integrating remote sensing, GIS and geography, PE&RS, Vol. 59 (10), pp1491-1496.

*Fung, T. and LeDrew, E. (1987)*: Application of principal component analysis to change detection, PE&RS, Vol.53 (12), pp 1649-1658.

*Fung, T. and LeDrew, E. (1988)*: The determination of optical threshold levels for change detection using various accuracy indices, PE&RS, Vol.54 (10), pp 1449-1454.

*Gong, P. (1993)*: Change detection using principal component analysis and fuzzy set theory, Canadian Journal of Remote Sensing, Vol.19 (1), pp 22-29.

*Howarth, P.J. and Boason, E. (1983*): Landsat digital enhancemnts for change detection in urban environments, Remote Sensing of Environment, Vol. 13, pp 149-160.

*Jensen, J.R., Cowen, D., Althausen, S., Narumalani, S. and Weatherbee, O. (1993a)*: An evaluation of coastwatch change detection protocol in South Carolina, PE&RS, Vol. 59 (6), pp 1039-1046.

*Jensen, J.R., Narumalani, S., Weatherbee, O. and Mackey, H.E. (1993b)*: Measurement of seasonal and yearly cattail and waterlily changes using multidate SPOT panchromatic data, PE&RS, Vol.59 (6), pp 519-525.

*Jensen, J.R., (1996)*: Introductory digital image processing, a remote sensing perspective, Second edition, Prentice Hall, New Jersey.

*Jaiju, LU. (1988*): Development of principal component analysis applied to multispectral landsat TM data, Int. J. of Remote Sensing, Vol. No.12, pp 1895-1907.

*Lo., C.P. (1986)*: Applied remote sensing, Longman Inc., New York.

*Malila., W.A., (1980)*: Change vector analysis:An approach for detecting forest changes with landsat, Proceedings, LARS Machine Processing of Remotely Sensed Data Symposium, W. Lafayette, IN:Laboratory for the Application of Remote Sensing, pp 326-336.

*Michalek, J.L., Wangner, T.W., Luczkovich, J.J. and Stoffle, R.W. (1993)*: Multispectral change vector analysis for monitoring coastal marine environment, PE&RS, Vol. 59 (3), pp381-384.

*Parviz Zeaiean Firouzabadi, Krishnamoorthy, R., Ramachandran., S. and Udaykumar, C. (1995)*: Application of fuzzy technique for mangrove area classification using indian remote sensing satellite data, Proceedings of the national conference on neural network and fuzzy systems, Anna University, Madras, Inida.

*Richards., J.A. (1984)*: Thmatic mapping from multispectral image data using the principal component transformation, Remote Sensing of Environment, Vol. 16, pp 35-46.

*Singh., A. (1989)*: Digital change techniques using remotely sensed data, Int. J. Of Remote Sensing, Vol. 10 (6), pp 989-1003.

*Spell, E.R., Kempka, R.G., Graves, K.J. and Cagney, T.P. (1995)*: Change detection of Pacific coast estuaries and bays using landsat thematic mapper, Presented in the Third thematic conference on remote sensing for marine coastal environments, Seattle, Washigton.

*Wang, F., (1990a)*: Fuzzy supervised classification of remote sensing images, IEEE Trans. on Geo. and Remote Sensing, 28:194-201.

*Wang, F., (1990b)*: Improving remote sensing image analysis through fuzzy information representation, PE&RS, Vol. 8,pp 1163-1169.

*Wang, F., (1993)*: A knowledge-based vision system for detecting land changes at urban fringes, IEEE Trans. On Geo. & Remote sensing, 31:136-145.

*Westmoreland, S. and Stow, D.A. (1992)*: Category identification of changed land-use polygons in an integrated image processing geographic information system, PE&RS, Vol.58 (11), pp1593-1599.

*Zadeh, L.A. (1965)*: Fuzzy sets, Information and control, Vol. 8, pp 338-353.

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