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Mapping of Vegetation Cover using Segment Based Classification of IKONOS Imagery

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ABSTRACT : This study was performed to prove if the high resolution satellite imagery of IKONOS is suitable for preparing digital vegetation map which is becoming increasingly important in ecological science. Seven classes for forest area and five classes for non-forest area were taken for classification. Three methods, such as the pixel based classification, the segment based classification with majority principle, and the segment based classification with maximum likelihood, were applied to classify IKONOS imagery taken in April 2000. As a whole, the segment based classification shows better performance in classifying the high resolution satellite imagery of IKONOS. Through the comparison of accuracies and kappa values of the above 3 classification methods, the segment based classification with maximum likelihood was proved to be the best suitable for preparing the vegetation map with the help of IKONOS imagery. This is true not only from the viewpoint of accuracy, but also for the purpose of preparing a polygon based vegetation map. On the basis of the segment based classification with the maximum likelihood, a digital vegetation map in which each vegetation class is delimitated in the form of a polygon could be prepared.

Key words : Digital vegetation map, IKONOS, Pixel based classification, Segment based classification.

INTRODUCTION

The classification procedure and method for remote sensed data should be selected considering the quality of the used data as well as the required information. The land cover map which just classifies the imagery into urban, forest, and water could be prepared with the satellite imagery of low resolution. However, a classification to tree species can be made only with the help of high resolution satellite imagery.

Since the commercial high resolution satellite imageries became available for nonmilitary area, their applications have rapidly increased in civil area. It has been widely accepted that higher geometric resolution reduces the proportion of mixed pixels and provides better interpretation possibilities. However the high geometric resolution can also increase the spectral variation within a class and make it difficult to apply the conventional pixel based method (Jensen 1996, Lillesand and Kiefer 2000) for classification.

So called the segment based classification (Mather 1999, Pal *et al.* 2000, Niemeyer 2001) can provide an alternative method for classifying the high resolution satellite imagery. The segment based classification makes it also possible to delimitate each class in the form of a polygon. So it has been evaluated to be suitable for preparing a polygon based thematic map like the vegetation map.

This study was performed to prove if the high resolution satellite imagery of IKONOS is suitable for preparing the digital vegetation map which gets increasing importance in ecological science. Futhermore this study aims at providing the suitable classification method for preparing the polygon based vegetation map using satellite imagery of IKONOS.

MATERIALS AND METHODS

Study area and materials

We used the IKONOS imagery taken in April 2000 in the middle of Kangwon Province which is located in the central eastern Korea (Fig. 1). The IKONOS imagery, which was taken for the area of 11 km x 11 km, is made up of the 4 spectral bands with 4m spatial resolution and 1 panchromatic imagery with 1m spatial resolution. Multispectral data was fusioned with the panchromatic data using IHS transformation. In the IHS transformation, a band combination of 3-4-1 was selected for the R-G-B color system. The fusioned image was then orthorectified with PCI OrthoEngine (PCI Geomatics 2001, Cho 2002).

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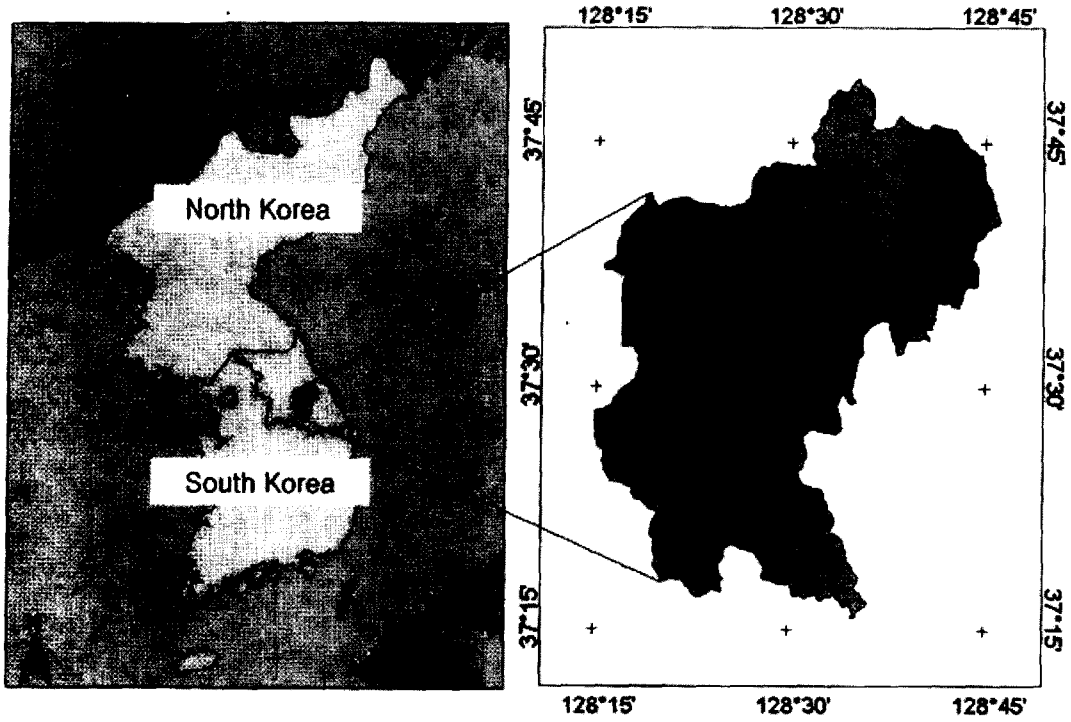

Fig. 1. Study area located in the middle of Kangwon Province.

The terrestrial survey was carried out to set the training area and get the reference data set in the study area. The same training or reference areas were used to compare the results of different classification methods. 260 reference areas (20 areas for each class) were randomly divided into two groups. One group was used for the classification and the other for the verification of the classification.

Classification schema

A suitable classification schema, in which all required classes are clearly defined, should be introduced for the classification.

Table 1. Classification schema for preparing vegetation map

Vegetaion	Class description	Abbrevation	Forest
Vegetation area	*Pinus densiflora*/-stand	PD	Forest area
	Larix leptolepis/-stand	PL	
	Pinus koraiensis/-stand	PK	
	Quercus spp./-stand	Q	
	Mixed stand	M	
	Coniferous mixed stand	C	
	Clear cutting area/young stand	F	Non-forest area
	Grass land	LP	
	Agricultural area (dry)	L.T	
	Agricultural area (wet)	L.N	
	Infrastructur	Infra	
Non-vegetation area	Water	Water	
	Other non-vegetation area	Other	

The numbers and types of classes generally depended on the remote sensed data used for classification as well as the required information. We used the high resolution satellite imagery of IIKONOS which can classify the land cover to tree species. The criteria of the forest type map (Korean Forest Research Institute: KFRI 1996) were taken as a basic class for preparing a vegetation map (Table 1).

Classification method

The classification of the IKONOS imagery was performed using the conventional pixel based method and the new segment based method. The supervised classification method with the maximum likelihood (Jensen 1996, ERDAS 1999, Lillesand and Kiefer 2000) was employed for the pixel based classification.

In the segment based classification (Dulyakarn *et al.* 1999, Mather 1999, Pal *et al.* 2000, Niemeyer 2001), the IKONOS imagery was segmented using eCognition which was developed by Definiens Imaging and gives the tools for the segment based classification (Definiens Imaging 2000). And each segment was again classified according to the spectral information of the pixels within the segment (Baatz and Schape 2000). Two methods of the majority principle and the maximum likelihood were applied to the segment based classification. In the segment based classification with the majority principle, pixels of each class which were classified by the pixel based method were counted using the GRID module of ArcInfo (ESRI 1995). And a class which

occupied a majority in a segment was assigned to the segment class.

In the segment based classification with maximum likelihood, the new segment-specific characteristics, which enable classification of each segment, were first derived. The spectral mean values and theirs standard deviations were employed as the segment-specific characteristics. Mean values and standard deviations for the spectral values of the pixels in each segment were calculated using eCognition. So a new data set of 6 artificial channels (3 channels for mean values and 3 channels for standard deviations) could be made for the classification of each segment. The classification using these 6 bands were performed with Imagine (ERDAS 1999).

Verification of classification

The result of classification was verified with the help of the independent reference data set, and the accuracies of the above three methods were compared. Kappa values (Congalton *et al.* 1983, Congalton and Mead 1983, Congalton 1991, Stehman, 1996) and error matrix (Janssen and van der Wel 1994, Jensen 1996, Congalton 1998, 1991, Stehman and Czaplewski 1998, Stehman 1999, Lillesand 2000) including producer's, user's, and overall accuracy were used for verifying the classification results and comparing the classification methods.

RESULTS AND DISCUSSION

Pixel based classification with maximum likelihood

1. Signature analysis

Fig. 2 shows the signature diagram of the various land cover (a) and the forest class (b) from the IKONOS imagery. The second channel (infrared channel) of the IKONOS data shows relatively good spectral differences among classes. However, the third channel (blue in multi-spectral data) has no big spectral differences for distinguishing vegetation classes. *Pinus dendiflora* stand (PD) and coniferous mixed stand (C), *Larix leptolepis* stand (PL) and deciduous-coniferous mixed stand (M) seem to be hardly distinguishable. This can be attributed to the complex species compositions of the mixed stands.

2. Classification and accuracy

After each pixel of the IKONOS imagery was classified through the maximum likelihood method, the result of the classification was verified with the help of an independent reference data set. The error matrix of the classification is displayed in Table 2. The forest area tends to show lower classification accuracy than the non-forest area. This can be attributed to the similar spectral value among the forest classes as well as the high geometric resolution of the IKONOS imagery. The high geometric resolution can cause the high dispersion of the pixel values and false classification within the same forest class. The stronger fluctuation of the forest surface in comparison to the non-forest area would have served as the reason for the lower accuracy in the forest area.

The coniferous mixed forest (C) shows the lowest producer's accuracy of 10.4%. Many of the coniferous mixed forests were classified into *Pinus densiflora* (PD) or *Larix leptolepis* (PL). Mixed stands (M) were also poorly classified with the producer's accuracy of 14.7%. This erroneous classification can be attributed to relatively high spectral variation which is caused by the

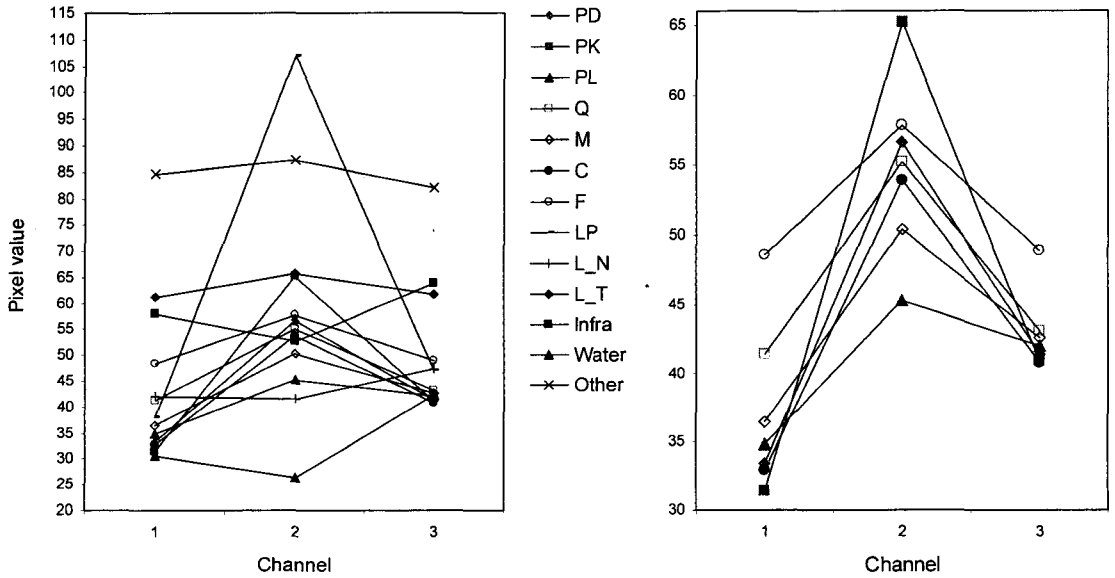

Fig. 2. Average spectral signature of IKONOS imagery for selected training area of various land cover(a)and forest class(b).

Table 2. Error matrix for the pixel based classification with maximum likelihood

Classes		Reference areas(m^2)													Sum	User's Accuracy
		PD	Pk	PL	Q	M	C	F	LP	L.N	L.T	Infra	Water	Other		
Classification results (m^2)	PD	25735	5302	2082	5801	8758	39116	389	3	12	0	0	0	0	8798	29.5%
	PK	19203	45596	342	2126	2910	21102	135	147	4	0	0	1	0	91566	49.8%
	PL	2648	520	118577	19347	67197	59094	1987	0	143	0	0	332	0	269845	43.9%
	Q	4891	214	4528	58031	26173	3408	17284	0	186	5	33	39	0	114792	50.6%
	M	2359	622	10834	17424	19568	13333	4816	1	178	0	11	40	0	69222	28.3%
	C	5063	1762	214	509	1844	15933	20	59	2	0	3	63	0	26472	60.2%
	F	1138	30	236	16549	5257	298	66226	0	670	190	493	23	0	91110	72.7%
	LP	2	20	0	6	2	1	0	47987	2	18	3	15	0	48056	99.9%
	L.N	60	5	1176	906	499	199	3985	0	37591	441	815	3638	0	49315	76.2%
	L.T	45	0	54	1346	557	78	4325	0	1778	28353	5776	29	1706	44047	64.4%
	Infra	0	0	0	18	5	0	102	0	2622	8022	52800	119	64	63752	82.8%
	Water	35	28	448	560	554	341	198	3	538	133	705	46303	6	49852	92.9%
	Other	0	0	0	2	0	0	69	0	0	10224	2404	0	31842	44541	71.5%
Sum		61215	54099	139491	122625	433324	152903	99536	48200	43726	47386	63043	50602	33618	1049768	
Producer's accuracy		42.0%	84.3%	85.3%	47.3%	14.7%	10.4%	66.5%	99.6%	86.0%	59.8%	83.8%	91.5%	94.7%	Overall accuracy: 56.6% Kappa value : 0.52	

high geometric resolution of IKONOS.

The grass land was classified most accurately with the producer' s accuracy of 99.6%. It is notable, however, that some of pixels were falsely classified despite their highly distinguishable spectral value. This might be caused by delimitation error of the reference area.

Segment based classification

1. Segment based classification with majority principle

The error matrix for the segment based classification with the majority principle is shown in Table 3. Through the segment based classification with majority principle, the overall accuracy could be improved from 56.6% in the pixel based classification to 65.7% and the kappa value from 0.52 to 0.62. While some segments were classified totally into a class and show 100% accuracy, no segment was classified into mixed forest (M and C). The

Table 3. Error matrix for the segment based classification wth majority principle

Classes		Reference areas(m^2)													Sum	User's Accuracy
		PD	Pk	PL	Q	M	C	F	LP	L.N	L.T	Infra	Water	Other		
Classification results (m^2)	PD	47388	0	0	0	0	36658	0	0	0	0	0	0	0	84046	56.4%
	PK	13827	54099	0	0	0	8027	0	0	0	0	0	0	0	75953	71.2%
	PL	0	0	139491	35288	121328	108218	0	0	0	0	0	0	0	404325	34.5%
	Q	0	0	0	87337	11996	0	0	0	0	0	0	0	0	99333	87.9%
	M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	F	0	0	0	0	0	0	93458	0	0	0	0	0	0	93458	100.0%
	LP	0	0	0	0	0	0	0	48200	0	0	0	0	0	48200	100.0%
	L.N	0	0	0	0	0	0	6078	0	43726	0	0	0	0	49804	87.8%
	L.T	0	0	0	0	0	0	0	0	0	28838	0	0	0	28838	100.0%
	Infra	0	0	0	0	0	0	0	0	0	10263	63043	0	0	73306	86.0%
	Water	0	0	0	0	0	0	0	0	0	0	0	50602	0	50602	100.0%
	Other	0	0	0	0	0	0	0	0	0	8285	0	0	33618	41903	80.2%
Sum		61215	54099	139491	122625	133324	152903	99536	48200	43726	47386	63043	50602	33618	1049768	
Producer's accuracy		77.4%	10.0%	100.0%	71.2%	0.0%	0.0%	93.9%	100.0%	100.0%	60.9%	100.0%	100.0%	100.0%	Overall accuracy: 65.7% Kappa value : 0.62	

Table 4. Error matrix for the segment based classification wth maximum likelihood

Reference areas(m^2) / Classes		PD	Pk	PL	Q	M	C	F	LP	L.N	L.T	Infra	Water	Other	Sum	User's accuracy
Classification results (m^2)	PD	42681	0	0	0	8343	26847	0	0	0	0	0	0	0	77871	54.8%
	PK	5205	54099	0	12975	0	8027	0	0	0	0	0	0	0	80306	67.4%
	PL	0	0	139491	0	17278	14536	0	0	0	0	0	0	0	171305	81.4%
	Q	0	0	0	89256	0	15253	0	0	0	0	0	0	0	104509	85.4%
	M	0	0	0	20394	107703	0	0	0	0	0	0	0	0	128097	84.1%
	C	13329	0	0	0	0	88240	0	0	0	0	0	0	0	101569	86.9%
	F	0	0	0	0	0	0	79848	0	0	0	0	0	0	79848	100.0%
	LP	0	0	0	0	0	0	0	48200	0	0	0	0	0	48200	100.0%
	L.N	0	0	0	0	0	0	0	0	40156	4270	0	0	0	44426	90.4%
	L.T	0	0	0	0	0	0	19688	0	0	25494	0	0	2577	47759	53.4%
	Infra	0	0	0	0	0	0	0	0	0	0	63043	0	0	63043	100.0%
	Water	0	0	0	0	0	0	0	0	3570	5993	0	50602	0	60165	84.1%
	Other	0	0	0	0	0	0	0	0	0	11629	0	0	31041	42670	72.8%
Sum		61215	54099	139491	122625	133324	152903	99536	48200	43726	47386	63043	50602	33618	1049768	
Producer's accuracy		69.7%	100.0%	100.0%	72.8%	80.8%	57.7%	80.2%	100.0%	91.8%	53.8%	100.0%	100.0%	92.3%	Overall accuracy: 81.9% Kappa value : 0.8	

coniferous mixed stands (C) were classified into other coniferous species (PD, PK, PL). And the mixed stands (M) were classified into *Larix leptolepis* (PL) or *Quercus class* (Q). This can be caused by the fact that the pixels in each segment were classified into other coniferous or oak class in the pixel based classification (see Table 2). So each pixel doesn' t represent mixed stands but just one of the species.

2. Segment based classification with maximum likelihood method

1) Signature analysis

The signature analysis was done in the same training area used in the pixel based classification. The signature diagram for the standard deviation is depicted in Fig. 2. In comparison to the signature for the pixel based classification (Fig. 3), better differences between *Pinus densiflora* (PD) and coniferous mixed stand (C) as well as between *Larix leptolepis* (PL) and deciduous mixed stand (M) could be found so that these classes might be better classified.

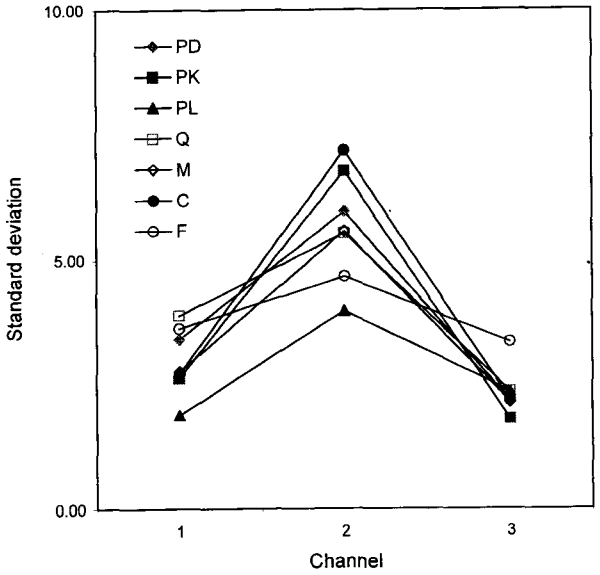

Fig. 3. Mean standard deviation of the IKONOS imagery on segment.

3. Classification and accuracy

The result of verification for the segment based classification with maximum likelihood is shown in form of the error matrix in Table 4. In comparison to the other previous two methods, the segment based classification with the maximum likelihood showed the best performance with the overall accuracy of 81.9% and kappa value of 0.8.

The two mixed forest classes (M and C), which were hardly classified in the other previous two methods, could be classified with the user' s accuracy of 85.4% and 84.1%. From the producer' s point of view, the coniferous mixed stands could be classified with the producer' s accuracy of 57.7%. The lowest accuracy was marked in agricultural dry land (L_T) with the accuracy of 54%. But through integration of the two agricultural classes into one class, the higher producer' s (76.7%) and user' s accuracy

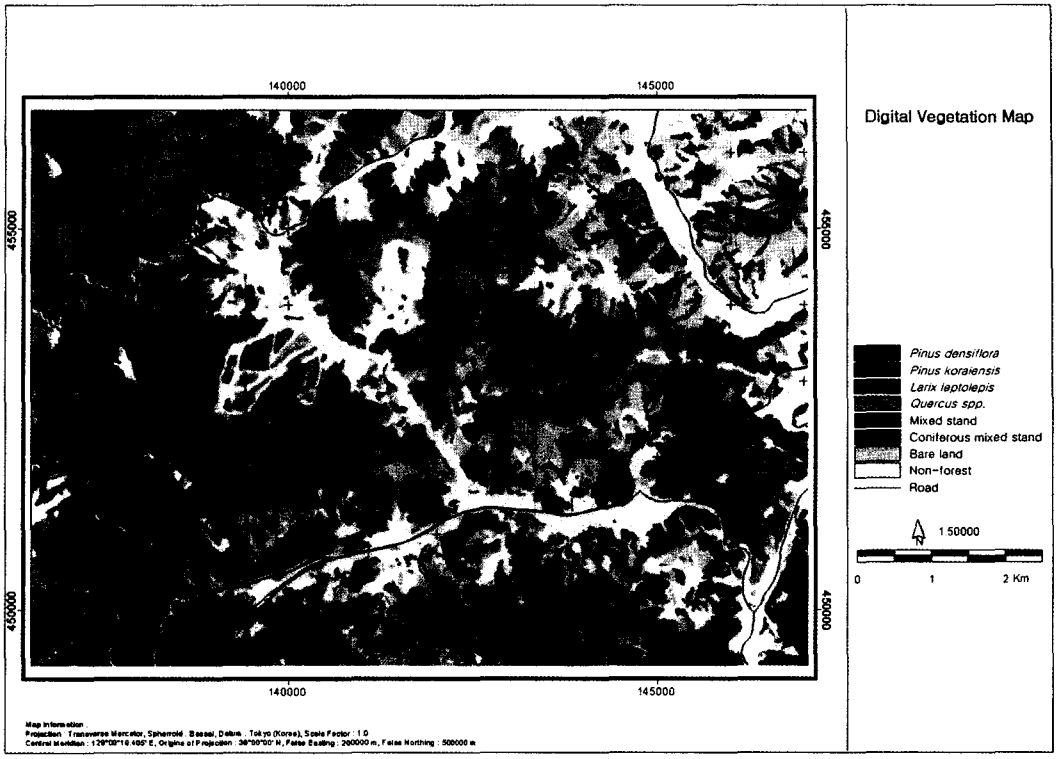

Fig. 4. Digital vegetation map produced from the segement based classification of IKONOS imagery.

(75.8%) could be obtained.

A good point of the segment based classification with maximum likelihood is that the charactersitics of the segment were newly made on the basis of the spectral information of the segment as well as the pixels in the segment.

Preparation of digital vegetation map

On the basis of the segment based classification with the maximum likelihood, a digital vegetation map in which each class was delimitated in the form of a polygon could be prepared (Fig. 4).

CONCLUSION

This study was performed to classify the vegetation type using the high resolution satellite imagery of IKONOS taken in April 2000. Seven classes for forest area and five classes for non-forest area were employed for classification. Three methods, such as the pixel based classification, the segment based classification with the majority principle, and the segment based classification with the maximum likelihood, were applied to classify the IKONOS imagery.

The pixel based classification with the maximum likelihood showed the poorest performance for classifying the vegetation type. The forest area tends to show the lower classification accuracy than the non-forest area. Especially, the mixed forest (C) shows the lowest producer' s accuracy.

Through the segment based classification with majority principle, the overall accuracy could be improved from 56.6% in pixel based classification to 65.7% and the kappa value from 0.52 to 0.62.

In comparison to the previous two methods, the segment based classification with the maximum likelihood showed the best performance with the overall accuracy of 81.9% and kappa value of 0.8. The two mixed forest classes (M and C), which were hardly classified in the previous two methods, could be classified with the user' s accuracy of 85.4% and 84.1%, respectively.

As a whole, the segment based classification with maximum likelihood was proved to be the best suitable for preparing the vegetation map with the help of the IKONOS imagery. This is true not only from the viewpoint of accuracy, but also for the purpose of preparing a polygon based vegetation map. On the basis of the segment based classification with the maximum likelihood, a digital vegetation map in which each class is delimitated in the form of a polygon could be prepared.

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