A new Neural Network architecture for automatic Urban Change Detection from Satellite Imagery

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Motivations

One of the most challenging problems addressed by the remote sensing community in current years is the development of effective data processing techniques for images acquired with the last generation of very high spatial resolution sensors.

Information on temporal dynamics of land cover in and around urban areas is needed for a variety of purposes:

- housing planning policy
- transportation planning policy
- environmental studies

Aim

The aim of this research is to develop a Change Detection Algorithm in order to obtain the accuracies required by typical applications.

→ A new method for urban change detection that greatly reduces the human effort needed to analyze the imagery:

NAHIRI: Neural Architecture for HIgh Resolution Imagery

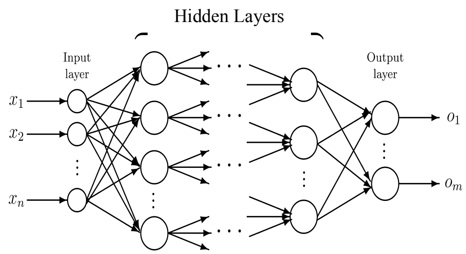
Change Detection algorithm based on Neural Networks able to exploit in parallel both the multi-band and the multi-temporal data to discriminate between real changes and false alarms.

Data Set

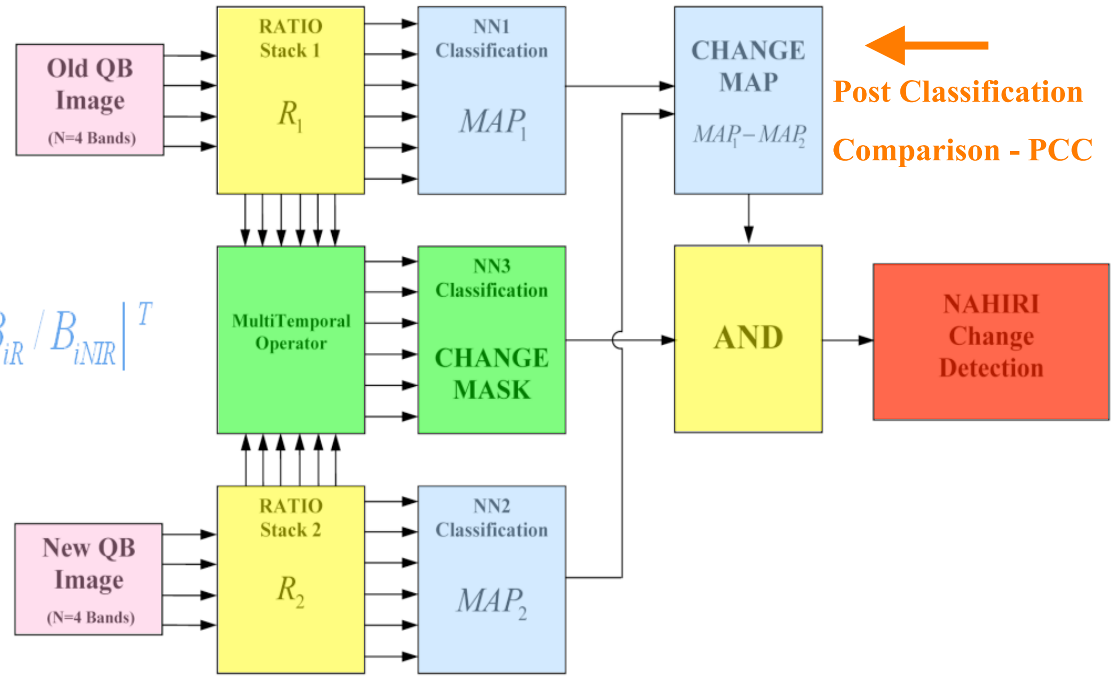
	Site Information		Image Information			
Data Set 1	**Location**	**Dimension (km^2)**	**Acquisition Date**	**Satellite**	**Spatial Res. (m)**	**Dimension (pixels)**
TEST AREA 1	Tor Vergata Campus, Rome, Italy	3.7	May 29, 2002	QuickBird	2.8	706 x 729
			March 13, 2003			
TEST AREA 2	Boulder, Colorado, U.S.A.	280	July 5, 1992	Landsat	30	664 x 432
			August 17, 1996			
TEST AREA 3	Boulder, Colorado, U.S.A.	0.4	August 14, 2002	QuickBird	0.6	1300 x 800
			July 6, 2004			
TEST AREA 4	Boulder, Colorado, U.S.A.	6.2	October 23, 2003	QuickBird	2.4	1382 x 800
			October 15, 2005			

NAHIRI Flow Chart

1. Choice of the inputs of the NNs



$$R_i = \left| B_{iB}/B_{iG}, B_{iB}/B_{iR}, B_{iB}/B_{iNIR}, B_{iG}/B_{iR}, B_{iG}/B_{iNIR}, B_{iR}/B_{iNIR} \right|^T$$



2. Topology of NN1 and NN2

Output - 4 Classes:

- *Man Made*
- *Vegetation*
- *Soil*
- *Water*

Multi-layer 6-12-12-4 Perceptron

3. *Change Map* = MAP1- MAP2

4. Multi-temporal Operator

$$\left| Log\{R_1(k)\} - Log\{R_2(k)\} \right|$$

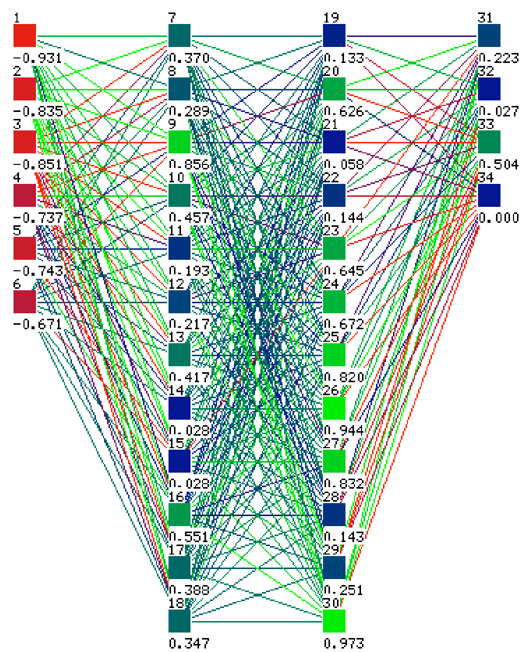
5. Topology of NN3: *Change Mask*

Output - 2 Classes:

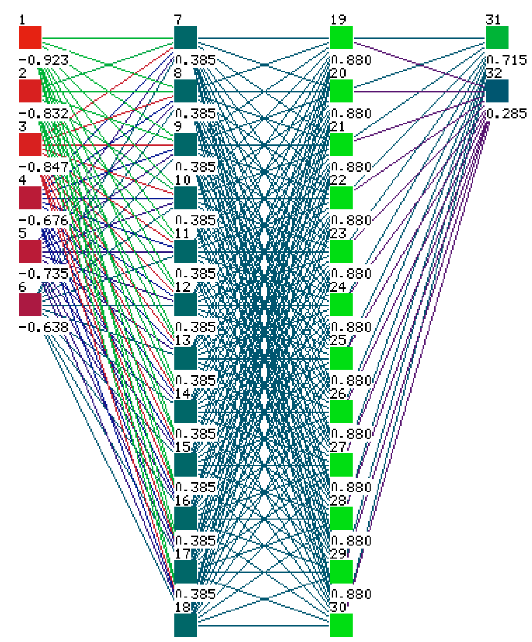
- *Change*
- *No Change*

Multi-layer 6-12-12-2 Perceptron

6. AND Gate: NAHIRI CD

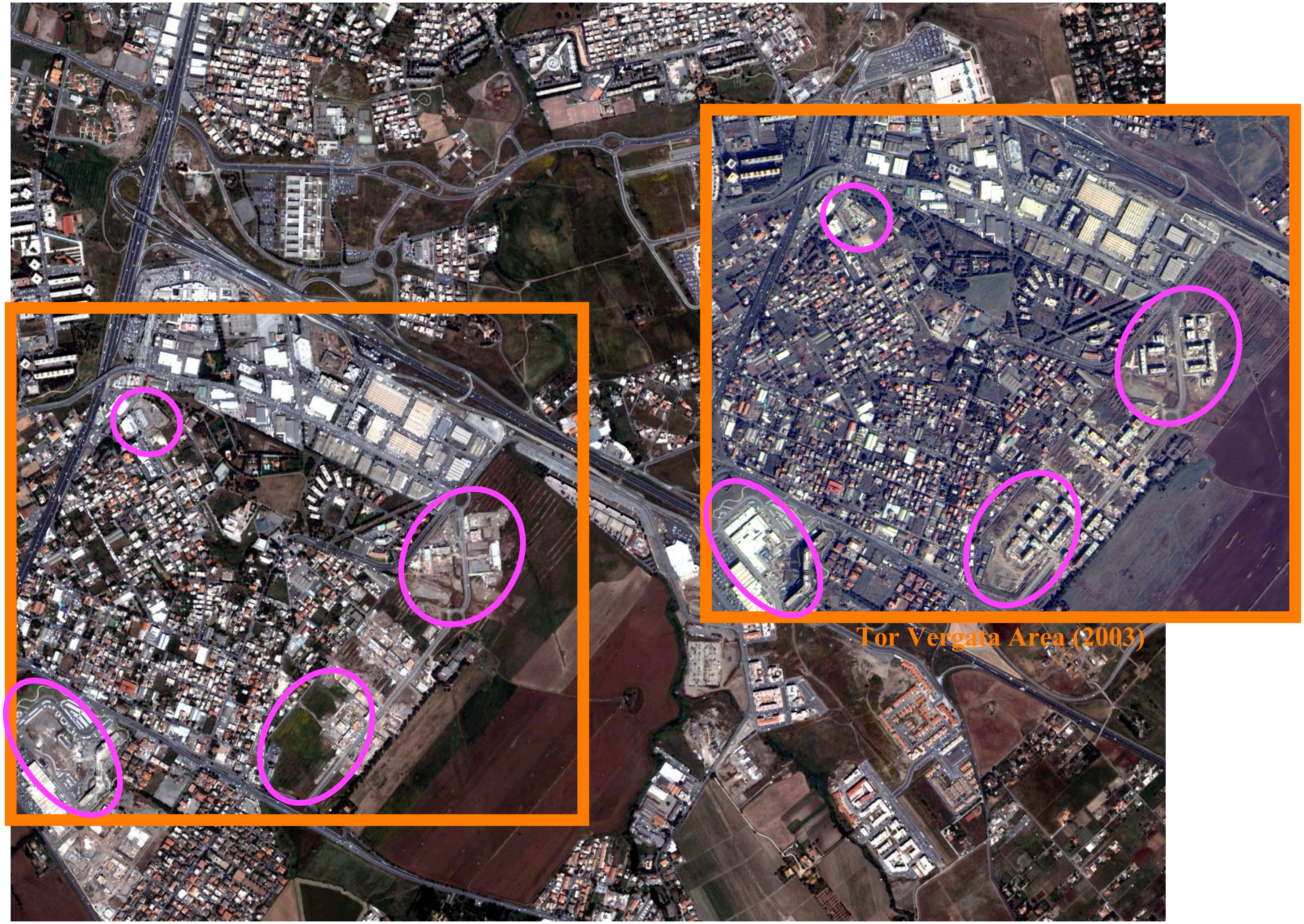


NN1 and NN2 Topology

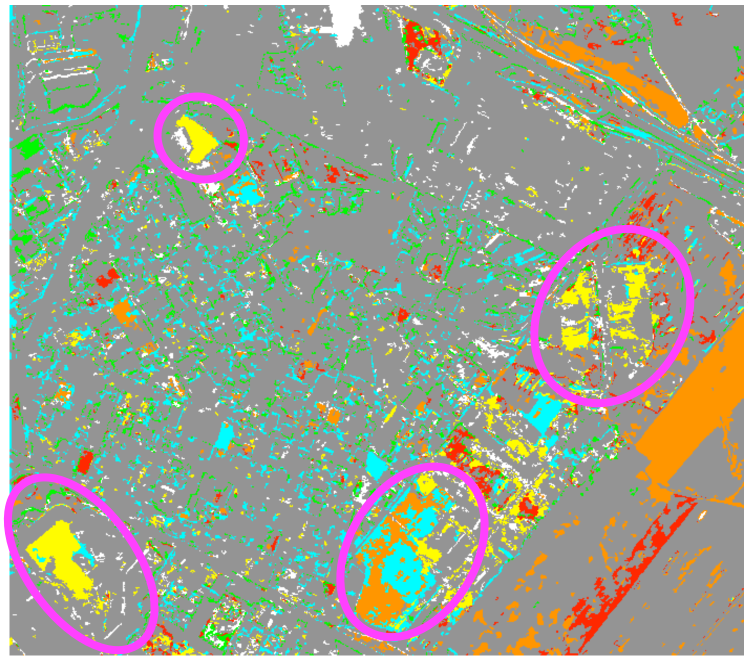


NN3 Topology

Test Area 1: Campus of the Tor Vergata University

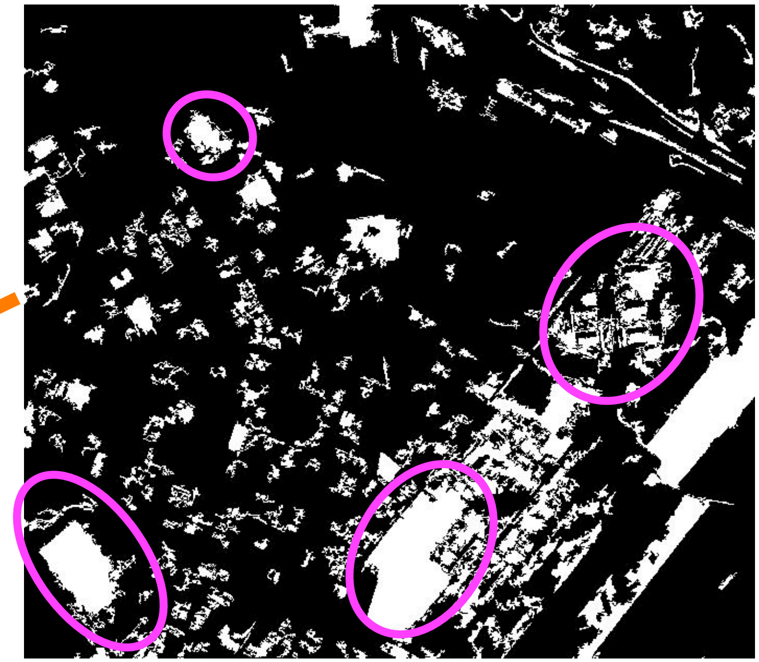


The campus of the Tor Vergata University is located in the upper part of the image. (2002)



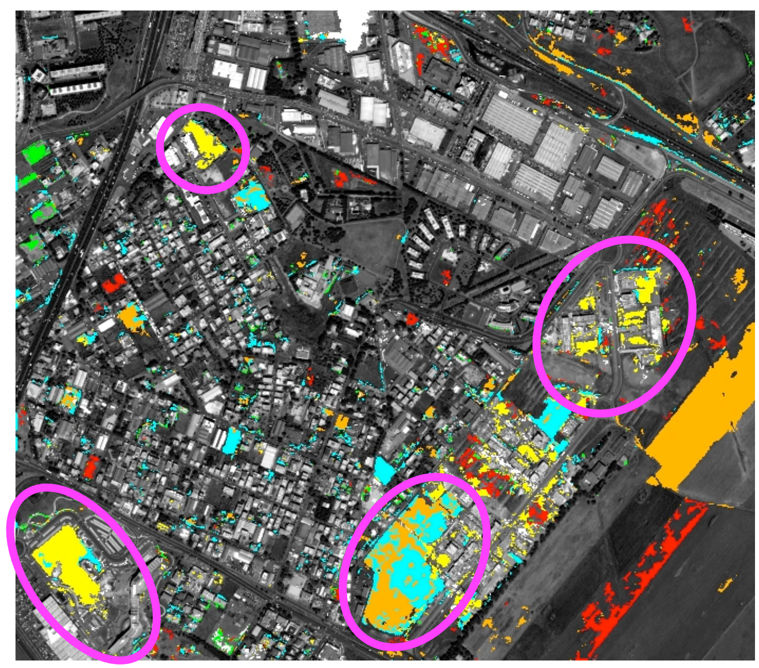
Change Map

AND



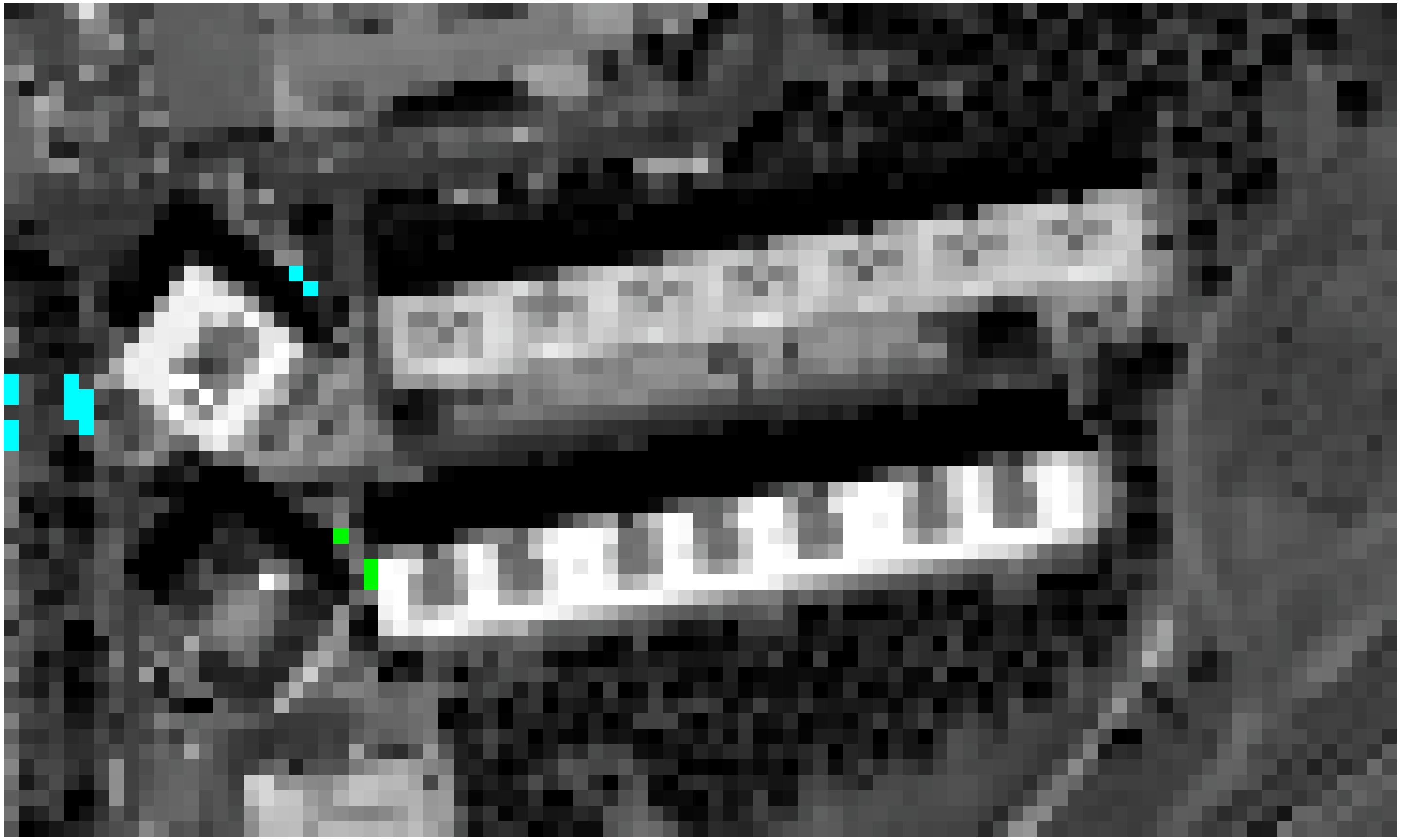
Change Mask

	2003		
2002	Vegetation	Man-made	Soil
Vegetation	Gray	Cyan	Orange
Man-made	Green	Gray	White
Soil	Red	Yellow	Gray

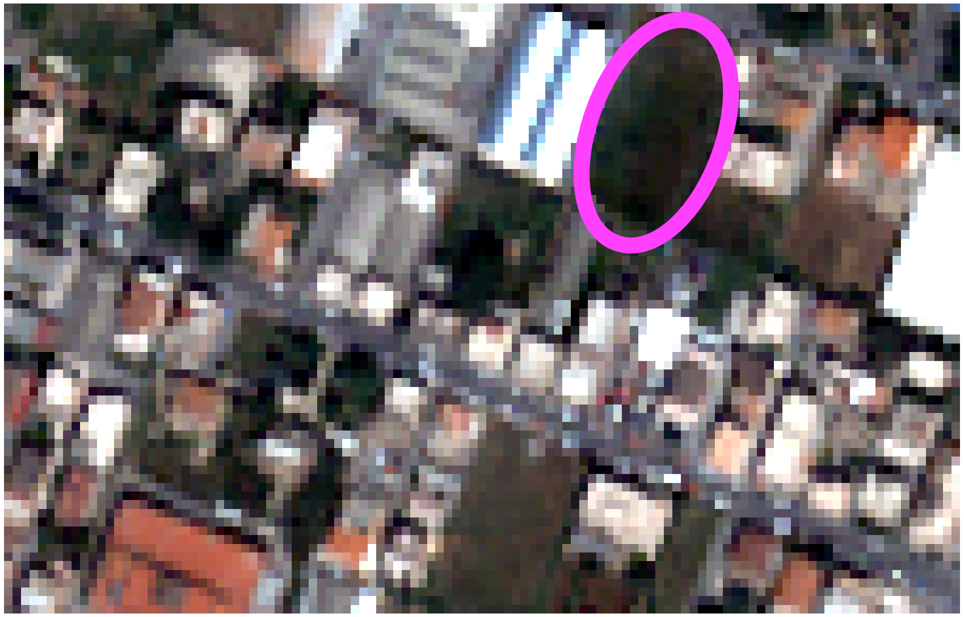


NAHIRI CD

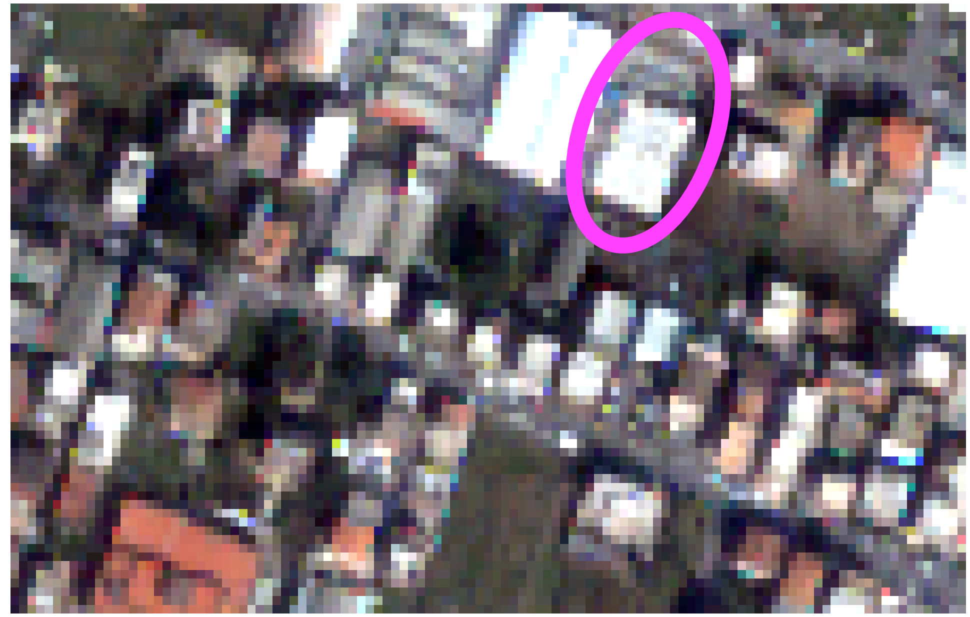
Test Area 1: Campus of the Tor Vergata University



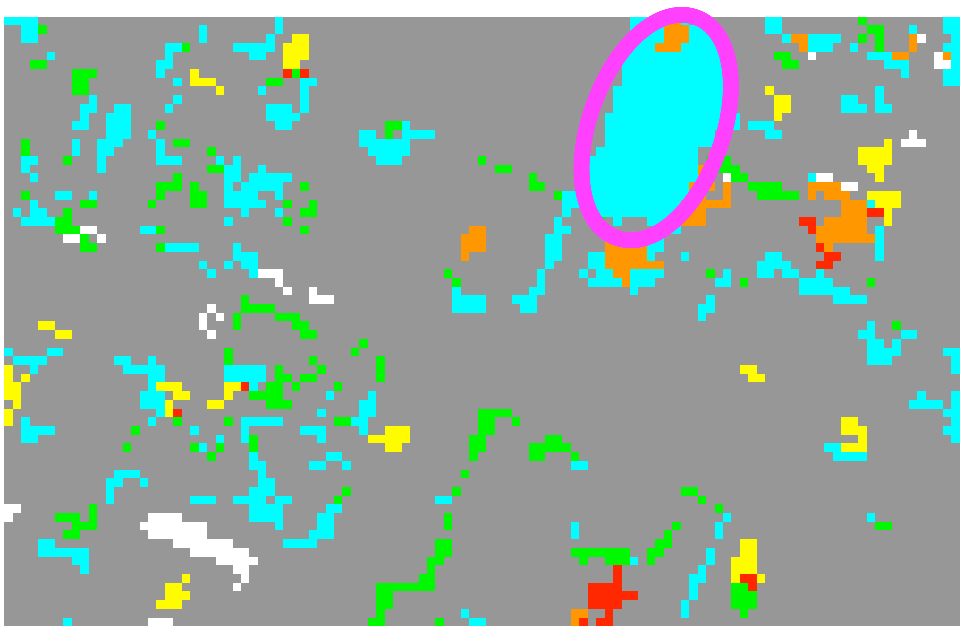
Test Area 1: Campus of the Tor Vergata University



(2002)



(2003)



PCC

NAHIRI

Test Area 1: Campus of the Tor Vergata University

2002 \ 2003	Green	Red	Yellow	Cyan	Orange	White	Gray	Total pixel	Excl. Error (%)
Green	1	0	0	0	0	0	0	0	0
Red	0	1	0	0	0	0	0	0	0
Yellow	0	0	1	0	0	0	0	0	0
Cyan	0	0	0	1	0	0	0	0	0
Orange	0	0	0	0	0	0	0	0	-
White	0	0	0	0	0	1	0	0	0
Gray	1	3	1	1	3	1	37	10	21.3
Total pixel	1	3	1	1	3	1	0	12	
Incl. Error (%)	50	75	50	50	100	50	0		

2002 \ 2003	Green	Red	Yellow	Cyan	Orange	White	Gray	Total pixel	Excl. Error (%)
Green	1	0	0	0	0	0	0	0	0
Red	0	1	0	0	0	0	0	0	0
Yellow	0	0	1	0	[illegible]	[illegible]	0	0	0
Cyan	0	0	0	[illegible]	0	0	[illegible]	0	0
Orange	0	0	0	0	0	0		0	-
White	0	0	0	0	0	1	0	0	0
Gray	0	0	0	1	0	0	46	1	2.1
Total pixel	0	0	0	1	2	0	0	3	
Incl. Error (%)	0	0	0	50	100	0	0		

Post Classification Comparison:

Overall error: 22.2%

Kappa Coefficient: 0.444

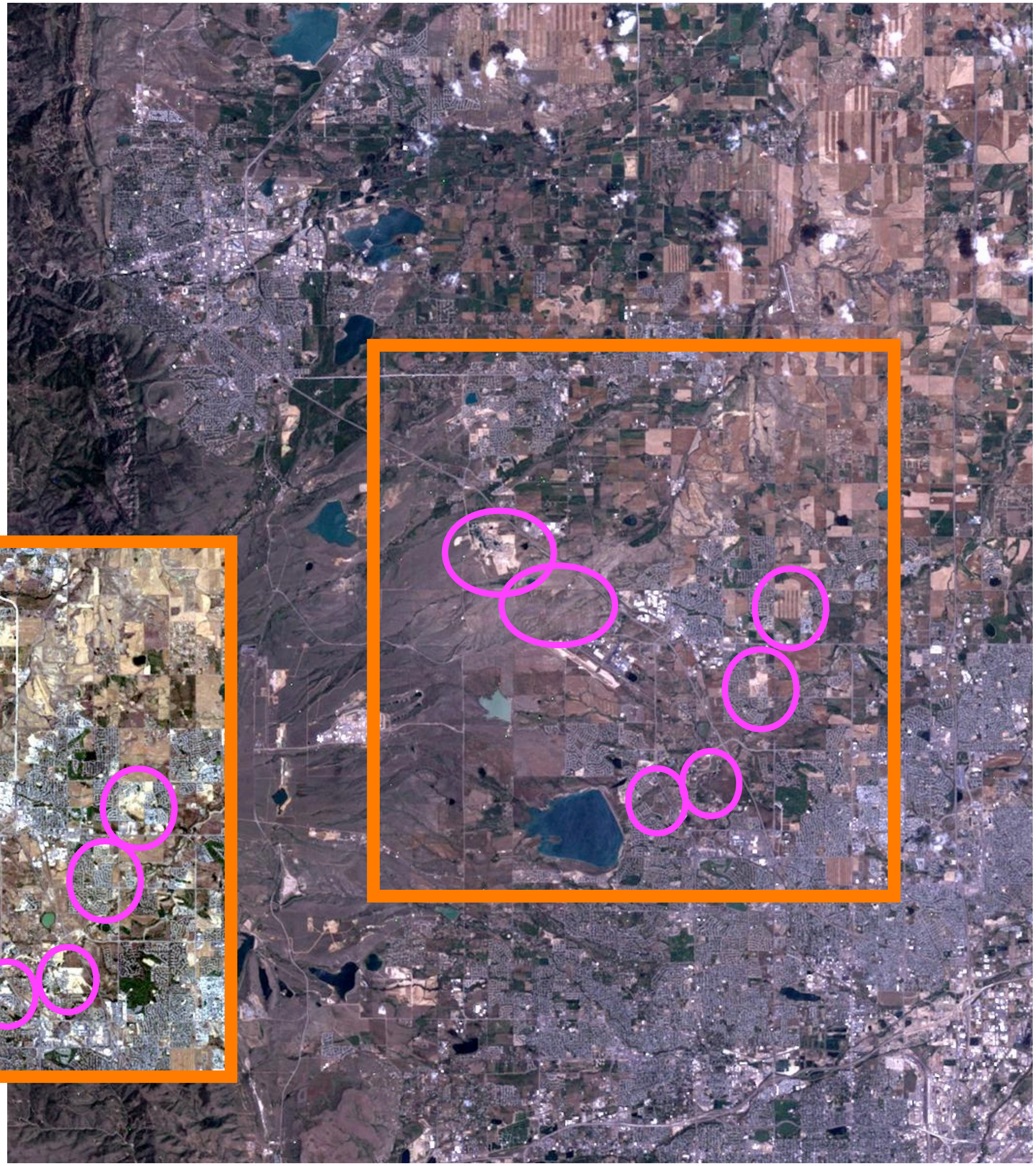
NAHIRI Change Detection:

Overall error: 5.5%

Kappa Coefficient: 0.783

Test Area 2: Boulder, Colorado, USA

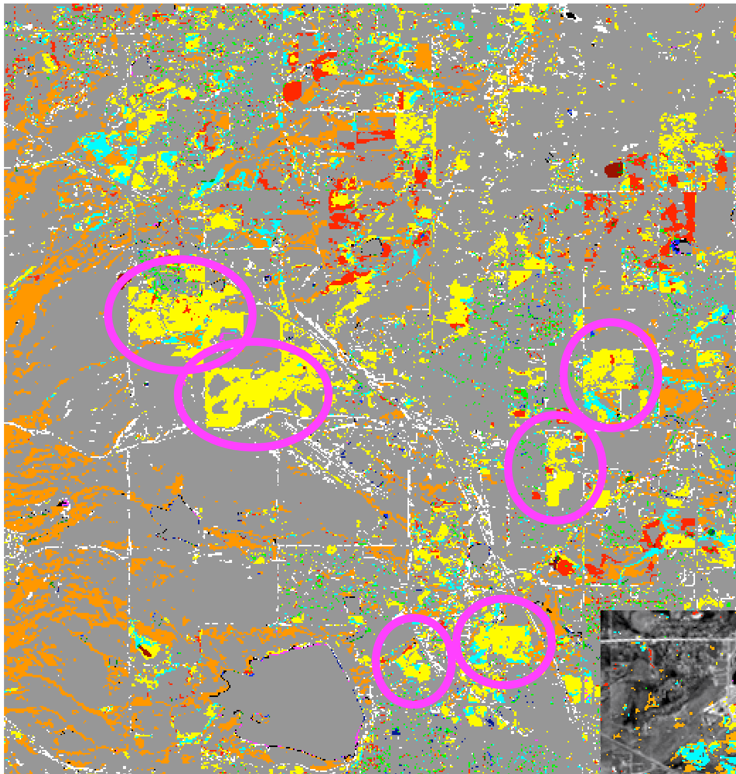
The Boulder study area is located northwest of Denver, Colorado, U.S.A.



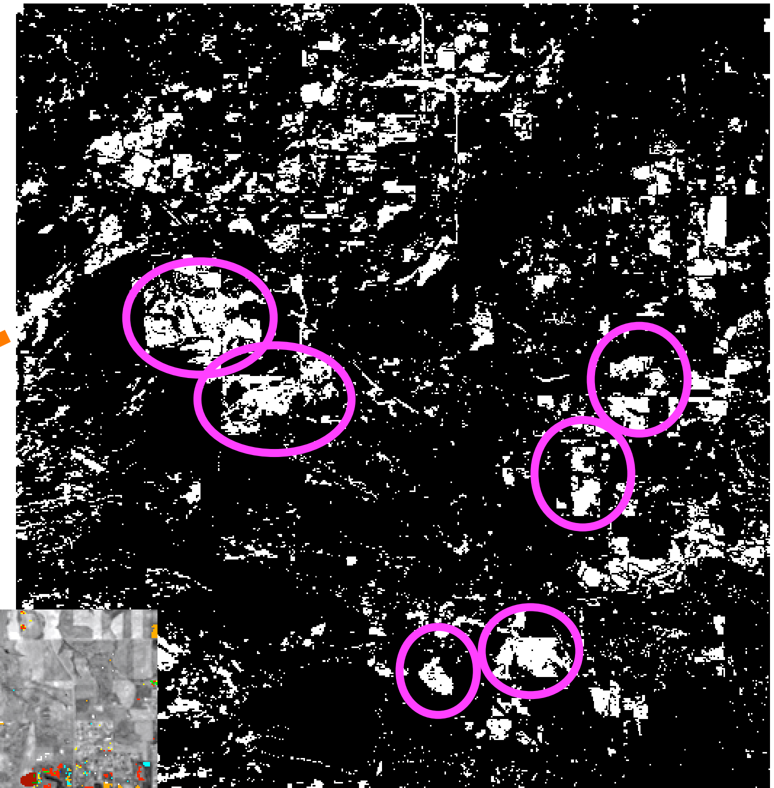
Boulder Area (1992)

Boulder Area (1996)

Test Area 2: Boulder, Colorado, USA

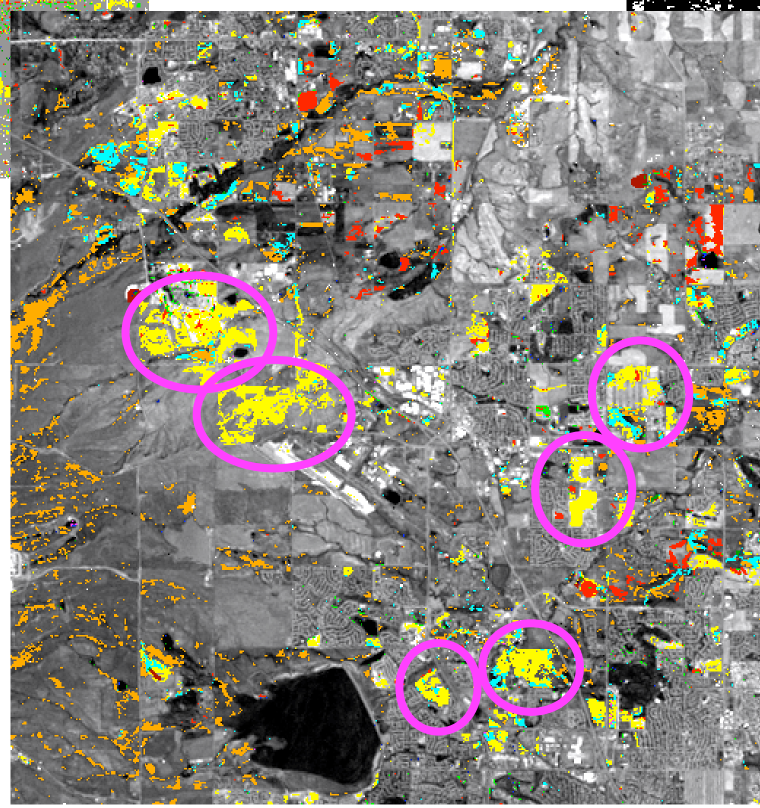


Change Map



Change Mask

AND

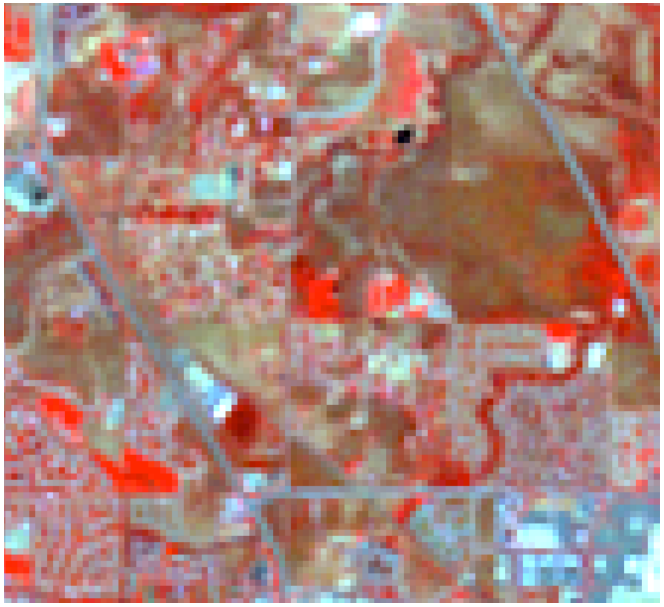


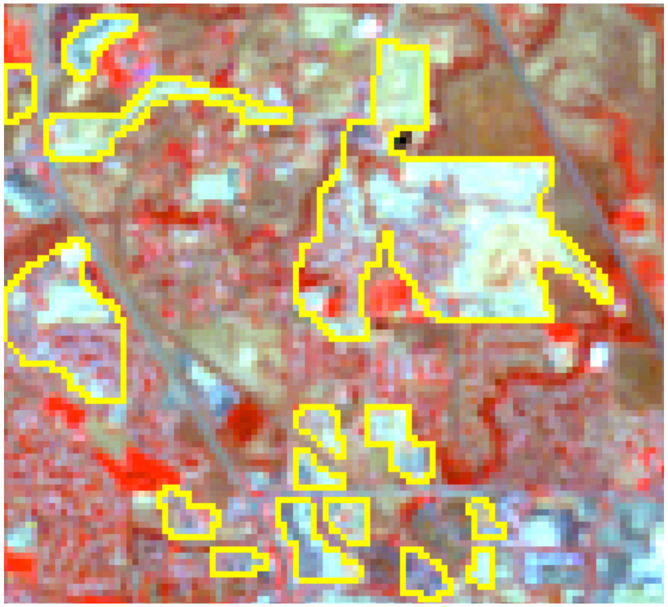
NAHIRI CD

	1996			
1992	Vegetation	Man-made	Water	Soil
Vegetation	Gray	Cyan	Dark Green	Orange
Man-made	Green	Gray	Dark Blue	White
Water	Blue	Magenta	Gray	Black
Soil	Red	Yellow	Brown	Gray

Test Area 2: Boulder, Colorado, USA

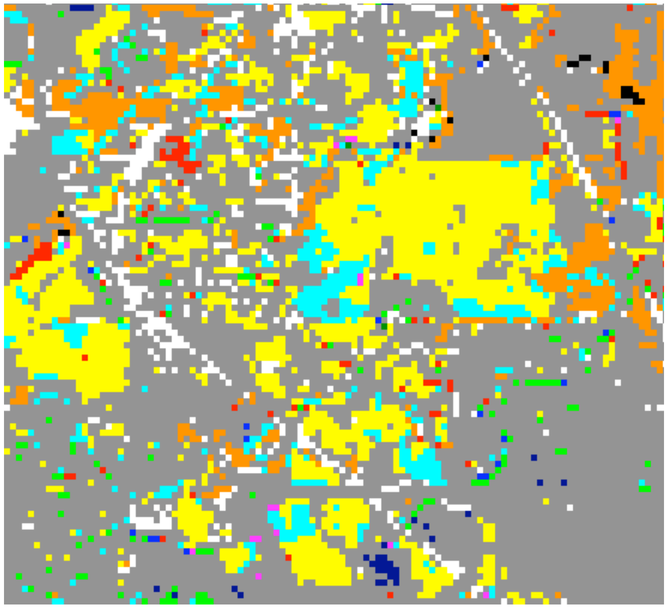
Boulder Area (1992)

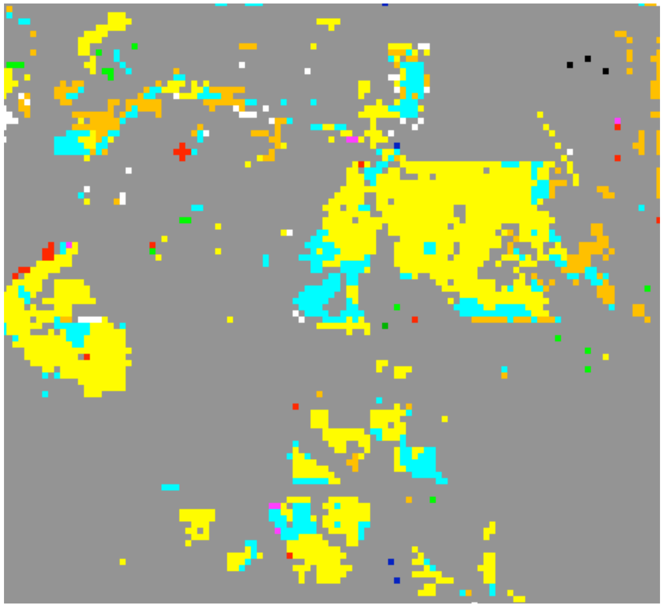




Boulder Area (1996)

PCC





NAHIRI

Test Area 2: Boulder, Colorado, USA

1992	Green	Red	Blue	Yellow	Magenta	Cyan	Dark Green	Brown	Dark Blue	Orange	White	Black	Gray	Total pixel	Excl. Error (%)
	1996														
Green	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Yellow	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Magenta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyan	0	0	0	0	1	1	0	0	0	0	0	0	0	1	50
Dark Green	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Brown	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Dark Blue	0	0	0	0	0	0	0			0			0	0	0
Orange	0	0	0	0	0	0			0	2	0			2	50
White	0	0	0	0	0			0	0	0	1				0
Black	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gray	0	0	0	0	0	0	0	0	0	0	0	0	44	0	0
Total pixel	0	0	0	0	1	0	0	0	0	0	0	0	2	3	
Incl. Error (%)	0	0	0	0	100	0	0	0	0	0	0	0	4.3		

NAHIRI Change Detection:

Overall error: 5%

1992	Green	Red	Blue	Yellow	Magenta	Cyan	Dark Green	Brown	Dark Blue	Orange	White	Black	Gray	Total pixel	Excl. Error (%)
	1996														
				0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0
				2	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0
				0	1	1	0	0	0	0	0	0	0	1	50
				0	0	0	1	0	0	0	0	0	0	0	0
				0	0	0	0	1	0	0	0	0	0	0	0
Blue				0	0	0	0	0	1	0	0	0	0	0	0
Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Black	0	0	0	0	0	0	0	0	0	2	0	1	2	4	80
Gray	1	1	0	0	0	0	0	0	0	4	0	0	38	6	13.6
Total pixel	1	1	0	0	1	0	0	0	0	6	0	0	2	11	
Incl. Error (%)	50	50	0	0	100	0	0	0	0	100	0	0	5		

Post Classification Comparison:

Overall error: 18.3%

Kappa Coefficient: 0.619

	2004			
2002	Vegetation	Man-made	Water	Soil
		yan	Dark Green	Orange
		ray	Dark Blue	White
Water	Blue	Magenta	Gray	Black
Soil	Red	Yellow	Brown	Gray

Test Area 3 (2002)

Why this site?

Change Map

e Test Area 2 n and includes

buildings

A fully Ground Truth of the area was a

One of th

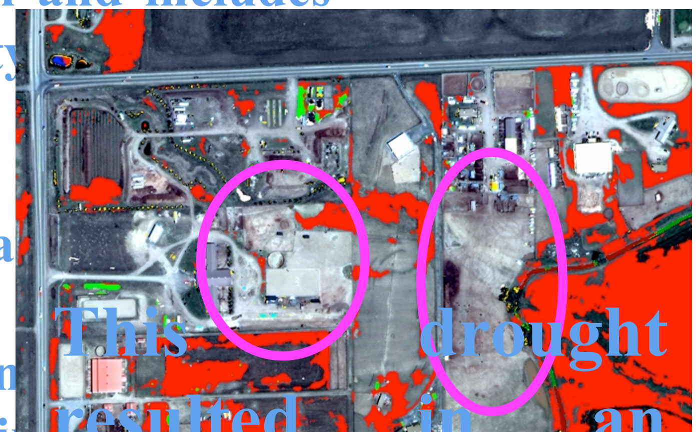
imagery is the

ng the image

Change Mask

Test Area 3 (2004)

NAHIRI CD



This drought resulted in an abundance of red pixels indicating change from the bare soil in 2002 to the seasonal vegetation in 2004.

Test Area 3: Boulder, Colorado, USA

NAHIRI														
Ground Truth	**Green**	**Red**	**Blue**	**Yellow**	**Magenta**	**Cyan**	**Dark Green**	**Brown**	**Dark Blue**	**Orange**	**White**	**Black**	**Gray**	**Total pixel**	**Excl. Error (%)**
Green	913	386	0	0	0	0	0	0	0	0	33	0	202	621	40.5
Red	4713	235620	0	1	0	0	0	0	0	0	63	0	28656	33433	12.4
Blue	0	6	0	0	0	0	0	0	0	0	0	0	13	19	100
Yellow	0	14	0	233	0	0	0	0	0	0	0	0	289	303	56.6
Magenta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
Cyan	133	6	0	3	0	55	0	0	0	0	0	0	33	175	76.1
Dark Green	8	0	0	0	0	0	862	708	0	0	0	2	1015	1733	66.8
Brown	2	6	0	62	1	0	4	1540	0	0	2	2	4174	4253	73.4
Dark Blue	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	0	0	-
Orange	1865	42	0	556	0	[illegible]	[illegible]	[illegible]	0	0	11	[illegible]	[illegible]	35697	100
White	12	3	0	0	0	[illegible]	[illegible]	0	0	0	45	[illegible]	[illegible]	[illegible]	88.5
Black	0	0	0	0	0	0	0	0	0	0	121	0	39	160	100
Gray	943	35605	0	1157	56	160	16	218	394	0	8344	29	677071	46922	6.5
Total pixel	7676	36068	0	1779	57	519	20	926	394	0	8586	33	677071	123661	
Incl. Error (%)	89.4	13.3	-	88.4	100	90.4	2.3	37.6	100	-	99.5	100	9.1		
Overall error: 11.9%							Kappa Coefficient: 0.722								

NAHIRI Change Detection:

Overall error: 11.8%

Post Classification Comparison															
Ground Truth	**Green**	**Red**	**Blue**	**Yellow**	**Magenta**	**Cyan**	**Dark Green**	**Brown**	**Dark Blue**	**Orange**	**White**	**Black**	**Gray**	**Total pixel**	**Excl. Error (%)**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	566	0	0	0	0	68	0	17217	19962	53.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	77	0	1085	6905	2.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	8	19	100
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	198	214	39.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	55	0	0	0	0	1	0	11	175	76.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	1320	943	0	0	0	2	238	1275	49.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	0	7	4214	0	0	2	8	1472	1579	27.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	-
Orange	[illegible]	[illegible]	[illegible]	[illegible]	0	359	0	0	0	0	11	0	32864	35697	100
White	50	7	0	39	0	1	0	0	0	0	82	0	211	308	79
Black	0	0	0	0	0	0	0	0	0	0	140	0	20	160	100
Gray	3721	47495	0	108332	59	478	16	218	473	0	23295	108	539798	184195	25.4
Total pixel	11569	48220	0	110543	60	1464	25	1161	473	0	23558	118	593122	250489	
Incl. Error (%)	40.1	15.5	-	99.7	100	96.2	1.7	21.6	100	-	99.7	100	9		
Overall error: 23.3%								Kappa Coefficient: 0.568							

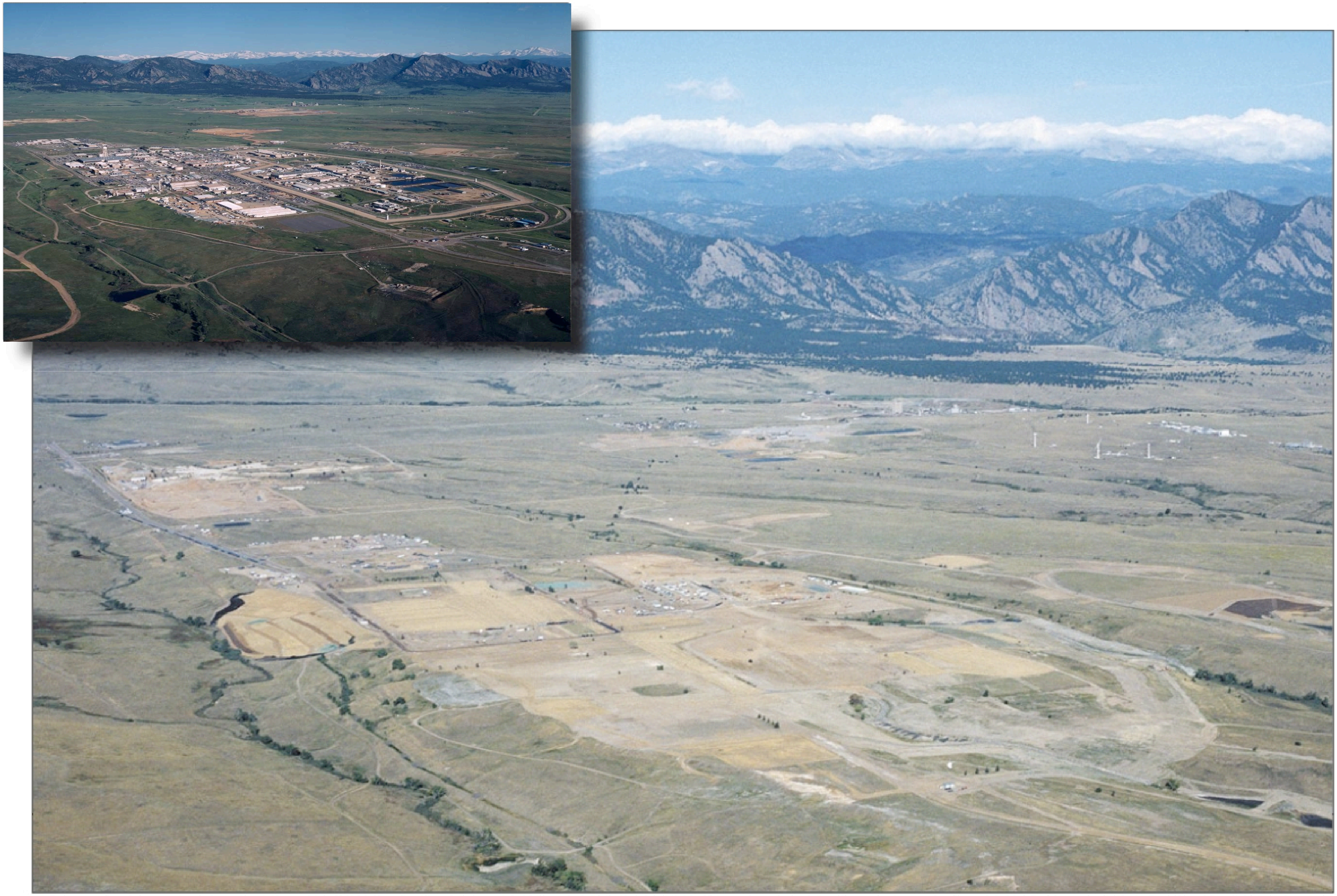
Post Classification Comparison:

Overall error: 23.3%

Kappa Coefficient: 0.568

Test Area 4: Boulder, Colorado, USA

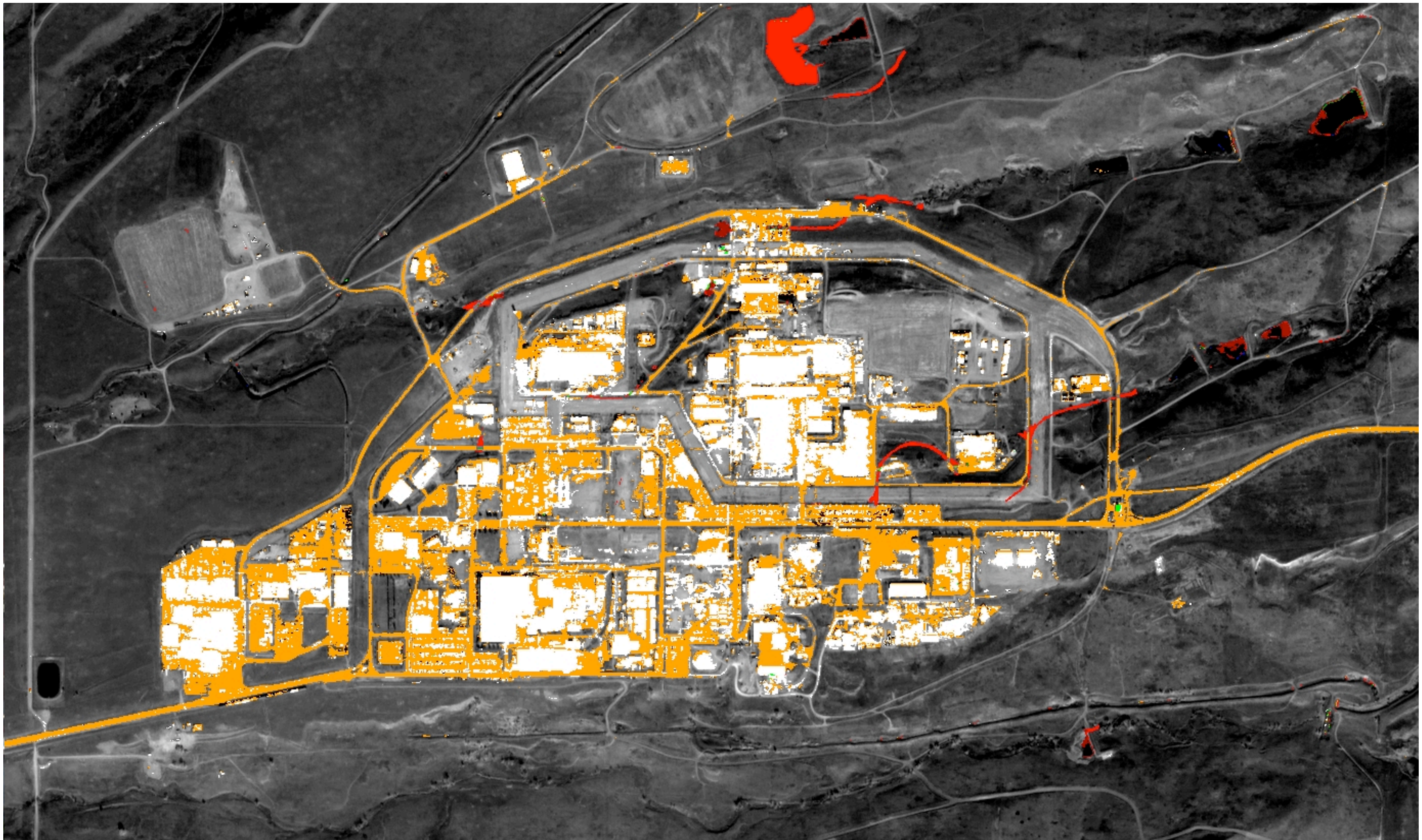
Boulder, called Rocky Flats, was chosen for the facility.



the negative direction.

Test Area 4 (about 2005)

Test Area 4: Boulder, Colorado, USA



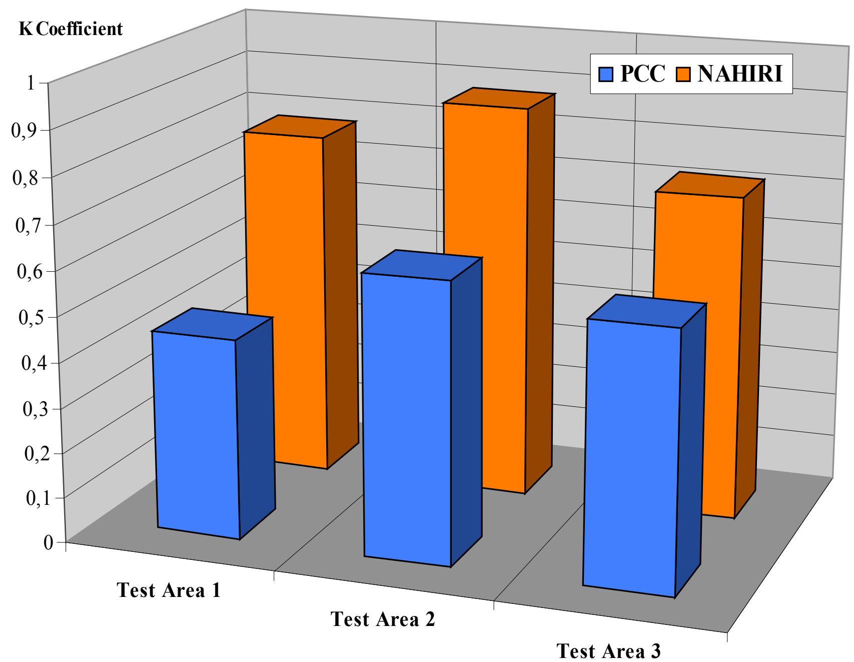
Test Area 4 (2005)

Man-made		Gray		White
Water			Gray	Black
Soil	Red		Brown	Gray

Conclusions

We developed a novel method based on a Neural Network Architecture for change detection that is able to process simultaneously multi-temporal and multi-band data.

	Location	Spatial Res. (m)	K-Coefficient NAHIRI	K-Coefficient PCC
Test Area 1	Tor Vergata Campus, Rome, Italy	2.8	0.783	0.444
Test Area 2	Boulder, Colorado, U.S.A.	30	0.881	0.619
Test Area 3	Boulder, Colorado, U.S.A.	0.6	0.722	0.568
		Mean	0.795	0.544



The mean of the *K-Coefficient* ranges from 0.544 in the case of PCC to 0.795 (NAHIRI) over very high and high resolution optical imagery.

Thank you for your attention!