Riparian Community and Aquatic Habitat Classification for the Shasta River

Prepared by:

Dr. Thomas B. Hardy
Shannon Clemens
Mark Winkelaar
Lisa Kent
R. Craig Addley

Utah Water Research Laboratory
Utah State University

Prepared for:

U.S. Fish and Wildlife Service

Contract No. 101811M757

April 17, 2006

I. Introduction

This project was undertaken in support of salmon and habitat restoration within the Shasta River drainage. The primary focus was to delineate both riparian and aquatic habitat within the study area based on classification of multi-spectral imagery. Ground truth data were provided by the USFWS for both riparian species and stream habitat types and were used to guide a combination of supervised and unsupervised classification for both riparian and stream habitats. Image classification results are provided for vegetation and stream habitats, including an error assessment of the classifications. A GIS project was also developed to allow resource managers access to both the raw and classified imagery.

II. Multi-Spectral Remote Sensing System Description

The Utah State University (USU) airborne multispectral digital system (Neale, 1991; Neale and Crowther, 1994) utilizes three Kodak Megaplus 4.2i digital frame cameras with CCD sensors containing 2044 x 2029 pixels. Interference filters placed over the 20 mm Nikon lenses form spectral bands centered in the green (0.55 μm), red (0.67 μm) and near-infrared (0.80 μm) portions of the electromagnetic spectrum. An Exotech four-band radiometer with Landsat Thematic Mapper bands TM1-4, with wavelengths similar to the digital camera spectral bands is used for the absolute calibration of the system in terms of radiance. The instruments are mounted on micrometer adjustable mounts so that the three cameras can be aligned to view the same area. Usually, the cameras are aligned to infinity and the registration of the imagery is done during post processing using procedures and automated routines developed in-house. The current USU system uses three EPIX frame grabbing and digital control boards in a special rack-mounted Pentium PC computer. The boards control the digital cameras through specially designed software, calculating the frequency of image acquisition according to altitude, speed and desired overlap between images. The software also allows for setting the camera shutter speed and automatically names and stores the files as they are acquired, using a selected project prefix. GPS-based coordinated universal time is used to co-locate the center of each image with GPS positions acquired at one-second intervals.

The system is mounted in a Piper Seneca II, through a hole in the belly of the aircraft in the rear baggage compartment. The three Kodak digital cameras are mounted inside a carbon graphite composite cylinder, which allows compensation of aircraft yaw angle. An equipment rack holds the computer, monitors, GPS encoders, S-VHS recorder, and thermal-IR scanner controller box. An INFRAMETRICS 760 thermal IR camera is also integrated for acquiring concurrent thermal infrared imagery and is mounted in front of the cylinder through its own porthole. The output of this camera is recorded on a S-VHS recorder for later digitization and processing. The IR camera was not deployed as part of this project. A color camera mounted through a third porthole provides color video footage with encoded GPS coordinates for a quick review of the area covered with the digital system. A second video camera is mounted in the nose of the aircraft at 60° and aids in the visual navigation of the aircraft when filming river systems.

III. Flightlines Acquisition

Imagery was acquired on 7/27/02. Based on the desired nominal 0.5 m resolution and terrain relief (which constrains flight parameters), aircraft altitude, lens used, and 1/f were determined. This gave a footprint for each image of approximately 1 square kilometer (2044 x 2029 pixels).

In total 339 3-band images were acquired. Since many images in adjacent flightlines overlap it was not necessary to use all the images. For example, all the images in shas0b were accurately covered by shas0a and shas0c, so none of the shas0b images were used. All the images in shas0d were covered by shas0c except for one. That image was added to the shas0c images and the combined flightline was renamed shas0cd. The shas1i flightline contained so many images that it was divided in half to make shas1i-upper and shas1i-lower flightlines. Shas1i-upper includes the first ten images from the original flightline and shas1i-lower includes the remaining ten images. A complete listing of the flightlines, number of images in each flightline, and the images used are provided in Table 1.

Table 1. Shasta River Flightlines

Flightline	Number of images	Images modeled	Flightline	Number of images	Images modeled
shas0a	7	all	shas0x	7	all
shas0b	6	none	shas0y	8	all
shas0c	10	all	shas0z	7	all
shas0d	7	shas0dr001f	shas1a	6	all
shas0e	5	none	shas1b	7	all
shas0f	5	all	shas1c	7	all
shas0g	7	all	shas1d	11	all
shas0h	9	all	shas1e	8	all
shas0i	3	none	shas1f	7	all
shas0j	7	all	shas1g	6	all
shas0k	7	none	shas1h	6	all
shas0l	9	all	shas1i	20	10 upper/ 10 lower
shas0m	9	all	shas1j	6	all
shas0n	6	all	shas1k	5	all
shas0o	8	all	shas1l	9	all
shas0p	4	none	shas1m	5	all
shas0q	11	all	shas1n	9	all
shas0r	8	all	shas1o	6	all
shas0s	8	all	shas1p	5	all
shas0t	7	all	shas1q	6	all
shas0u	6	all	shas1r	8	all
shas0v	6	all	shas1s	5	none
shas0w	10	all	shas1t	10	none

The prefix Shas (for Shasta River) was given to all flightlines followed by a number (starting at zero and increasing) and a letter in alphabetical order from a to z. The aircraft computer program that operates the cameras added the number and letter to each flightline in the sequence it was acquired. The flightlines begin with shas0a at the Klamath River confluence and move upstream. The shas0z flightline is followed by shas1a with and the alphabetic sequence continues to the headwaters in shas1t. An overview showing the layout of all the flightlines on the Shasta River is given in Figure A1 in Appendix A.

IV. Processing

Processing of the raw imagery to allow classification and analysis consists of numerous steps.

1) Geometric correction – Lens imperfections cause geometric distortions that increase at the edges of the image scene.
2) Vignetting/Sensor sensitivity – Vignetting and variation in the sensitivity of the sensor chip result in non-uniform readings for uniform input radiation.
3) Rectification – The individual spectral bands are registered to the same image coordinate system to allow construction of the 3band composite image file.
4) Radiometric – Normalization of each scene to correct for differences in uniform solar irradiance due to time difference, haze, etc.

After these processing steps, individual scenes are ready for classification and analysis. The individual images were stitched into mosaic strips and registered to a geographic or local coordinate system to produce orthophotos for each flightline prior to processing.

Land classification on the Shasta began with using digitized ground truth polygons in ERDAS Imagine 8.7 to define a signature. The signature was evaluated using a seperability matrix to delete overlapping classes, while missing classes such as shadow and open ground were added. After four iterative signature evaluation steps the final land classification was created using supervised classification.

The vegetation layers were extracted from the land classified images for further unsupervised classification using the Iterative Self-Organizing Data Analysis Technique (ISODATA) (Tou and Gonzalez, 1974) clustering method, which uses spectral distance as in the sequential method, but iteratively classifies the pixels, redefines the criteria for each class, and classifies again, so that the spectral distance patterns in the data emerge. The maximum number of iterations was set at 24 and the convergence threshold used was 95%. Six classes were used for ISODATA classification. Every image in each flight line was visually inspected using ArcView GIS 3.2 to interpret the classes that were created. Ground truth data were used, where available, to identify patterns that indicate certain groups or patterns in the imagery associated with features on the ground.

The aquatic habitat class signatures were produced using ISODATA on the water layer extracted from the land-classified images. After evaluation of the resulting clusters, it was determined that the river features were best defined using four classes. The maximum number of iterations was set at 24 and the convergence threshold used was 95%. The vegetation and aquatic habitat images were combined to produce classified images for each flightline.

V. Classification Results

To interpret the vegetation classes produced using ISODATA each flightline was inspected and grouped with neighboring flightlines that contained similar topography and vegetative growth patterns. This resulted in three major groups of flightlines for which common class descriptions could be determined. Appendix A contains images of each flightline including an orthophoto on the left showing the topography and a classified image on the right showing the vegetation and aquatic habitat classes.

Table 2 gives the vegetation class descriptions for Shas0a through Shas0h with some species specific identifying patterns determined from ground truth data given below.

Table 2. Vegetation Class Descriptions for Shas0a – Shas0h

	1 Upland shrubs and trees
	2 Shrubs and herbaceous species (Ceonothus, Poison Oak, California Grape)
	3 Upland shrubs/small trees
	4 Riparian forb communities and sedges
	5 Riparian willow/alder with wet site forbs/grasses/sedges
	6 Grasses and forbs

These flightlines were grouped together based on having similar topography and vegetation patterns as can be seen in Appendix A, Figures A2 through A6. The general topography of this section includes canyon characteristics such as steep side slopes and a confined channel.

Adjacent to the river, a pattern of pink in the center surrounded by light green with dark green on the edges is typical of Alder, Sandbar Willow and Arroyo Willows. Rush and sedges also have a similar pattern. Figure 1 shows typical Alder found alongside the river. This pink and green combination is also found in other tree species. Ponderosa Pines are commonly circular in shape with light green in the center, often with a spot of pink, a band of pink on the bottom and a band of dark green on the top. Figure 2 shows two of the Ponderosa Pine. Other trees such as Black Oak and Maple Small Leaf commonly have pink centers surrounded by light green, edged with dark green. Figure 3 shows two Black Oak (top) and one Maple Small Leaf (bottom). Trees such as White Oak have a pattern of light and green surrounded by dark green edges. Figure 4 shows a group of White Oak. Junipers are identified by a center of light green also with a band of blue on the bottom with dark green on the top. This color combination identifies Juniper in upland areas, not touching the river. A group Juniper can be seen in Figure 5. Manzanitas, shown in Figure 6, have a pattern similar to Juniper.

The vegetation classifications given in Table 3 were used for Shas0j through Shas0z with certain patterns identified by ground truth data. These flightlines were grouped together based on having similar topography and vegetation patterns as can be seen in Appendix A, Figures A7 through A21. The general topography of this group includes a wide flood plain, wet meadows, and gradual side slopes.

Table 3. Vegetation Class Descriptions for Shas0j – Shas0z

1 Shrubs and trees/standing water/wetland
2 Trees/crops
3 Upland shrubs/wet vegetation
4 Grasses/fields
5 Riparian Willow/Alder, wet meadow/crops
6 Grasses/fields

Adjacent to the river, groups with pink outlined by light green and dark green indicate Arroyo Willow (shown in Figure 7) and trees such as Alder. Combinations of pink and light green not touching the river are wet meadows and irrigated fields. Figure 8 shows the pattern found in an irrigated alfalfa field. Fallow fields and similar non-riparian zones with bare ground and grasses are grey and orange. Figure 9 shows the pattern found in a fallow field near but not touching the river. Light and dark green patches immediately adjacent to the river indicate trees. Dark green patches further away from the river indicate standing water or very moist areas such as wetlands. Large areas of single colors indicate meadows and fields with various height of vegetative cover and a range of moisture contents. Clusters of three or more colors are generally trees and shrubs. Clusters of trees and shrubs cover upland areas with steeper slopes. Common patterns for these include bands of blue with light and dark green above. Figure 10 shows a group of trees growing on a hillside above the floodplain.

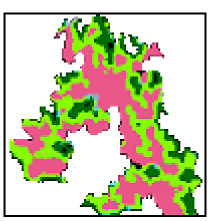

Figure 7. Arroyo Willow

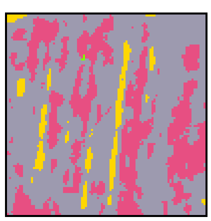

Figure 8. Irrigated Field

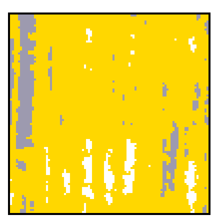

Figure 9. Fallow Field

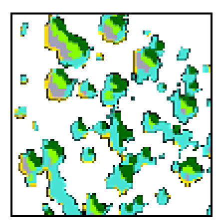

Figure 10. Upland Tree Cluster

The vegetation classification used for Shas1a through Shas1r is shown in Table 4. Although no ground truth data were provided for any of the shas1 images, the vegetation classes are similar to that seen in the shas0 images. The topography and vegetation patterns for the shas1 sections can be seen in Appendix A, Figures A22 through A40.

Table 4. Vegetation Class Descriptions for Shas1a – Shas1r

1 Shrubs and trees/standing water/wetland
2 Trees/crops
3 Upland shrubs/wet vegetation
4 Grasses/fields
5 Riparian Willow/Alder, wet meadow/crops
6 Grasses/fields

The topography of this section varies. From Shas1a upstream to Shas1c is forest. The channel is narrow and the side slopes are steep, covered mainly by trees such as juniper. In the upper portion of Shas1c upstream to Shas1f, the flood plain becomes wider and side slopes are more gradual. More riparian vegetation exists, as well as wet meadows and both irrigated and fallow fields. Shas1h, Shas1i-upper and Shas1i-lower show trees lining the shore of Lake Shastina. Above the lake the channel is wider with large trees lining the river and marshes and wet meadows further from the river.

Upland areas in sections with steep side slopes are commonly covered with trees as shown in Figure 11. These trees are juniper and similar species. Riparian vegetation found in sections with wide flood plains includes patterns as shown in Figure 12 representing willow, alder and similar species. Also common in areas where the channel is wide and side slopes are mild are wet meadows, shown in Figure 13. Above Lake Shastina dense tree growth occurs in both riparian and upland areas as shown in Figure 14.

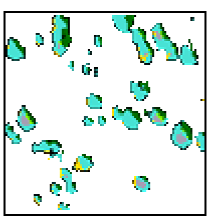

Figure 11. Upland Trees

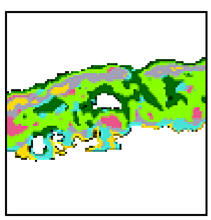

Figure 12. Riparian Vegetation

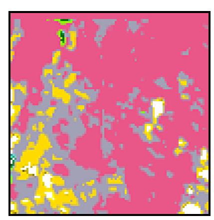

Figure 13. Wet Meadows

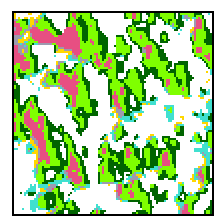

Figure 14. Riparian and Upland Trees

The aquatic habitat classes produced using ISODATA were consistent throughout all the flightlines resulting in one water class description for the entire Shasta River, shown in Table 5. The resulting classified water images were visually evaluated against ground truth data and estimated to be 90% accurate. This classification applies only to the Shasta River and not to Lake Shastina or other non-river water bodies.

Table 5. Shasta Water Classification

1	Pool/Deep Glide
2	Run/Shallow Glide
3	Riffle
4	Shallow/Turbulent

No ground truth data including linear measurements for accuracy assessment were provided; therefore a formal assessment of this imagery could not be completed. However, based on previous studies comparing the differences between predicted and observed linear measurements for low-resolution flight data, the expected accuracy for this project on the Shasta River is $\pm$ 0.91 meters (Panja, 1994).

VI. References

Neale, C.M.U. 1991. An airborne multispectral video/radiometer remote sensing system for agricultural and environmental monitoring. Pages 293-299 in Automated Agriculture for the 21st Century. Proceedings of the ASAE Symposium, December 16-17, Chicago, Illinois.

Neale, C.M.U. and B.G. Crowther. 1994. An airborne multispectral video/radiometer remote sensing system: development and calibration. Remote Sensing of Environment 49:187-194.

Panja, K.V. 1994. Classification of mesoscale hydraulic features based on spectral analysis of multispectral aerial videography. Masters Thesis, Utah State University.

Tou, J. T., and R. C. Gonzalez. 1974. Pattern Recognition Principles. Reading, Massachusetts: Addison-Wesley Publishing Company.

Appendix A

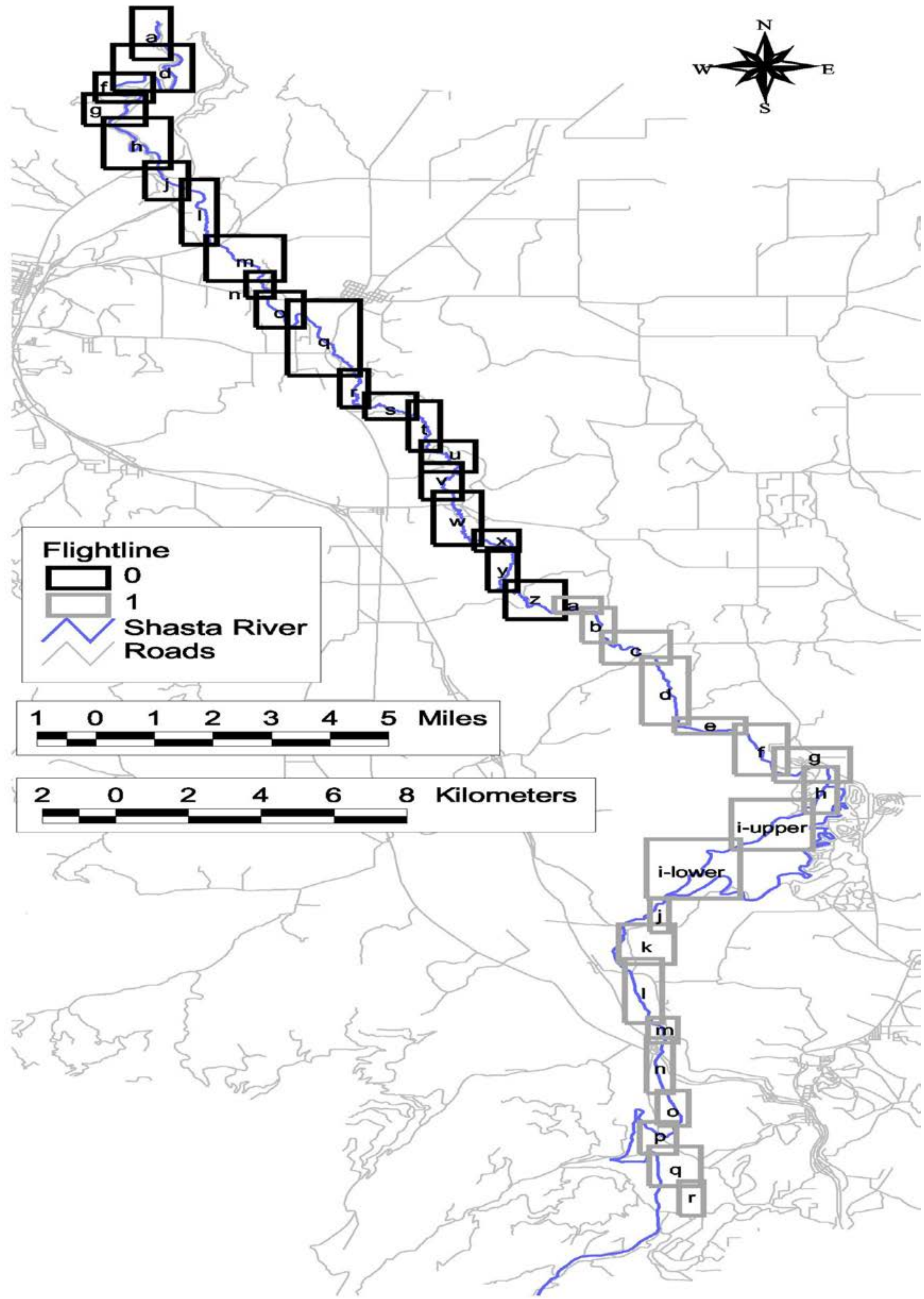

Figure A1. Overview of Shasta River Flightlines

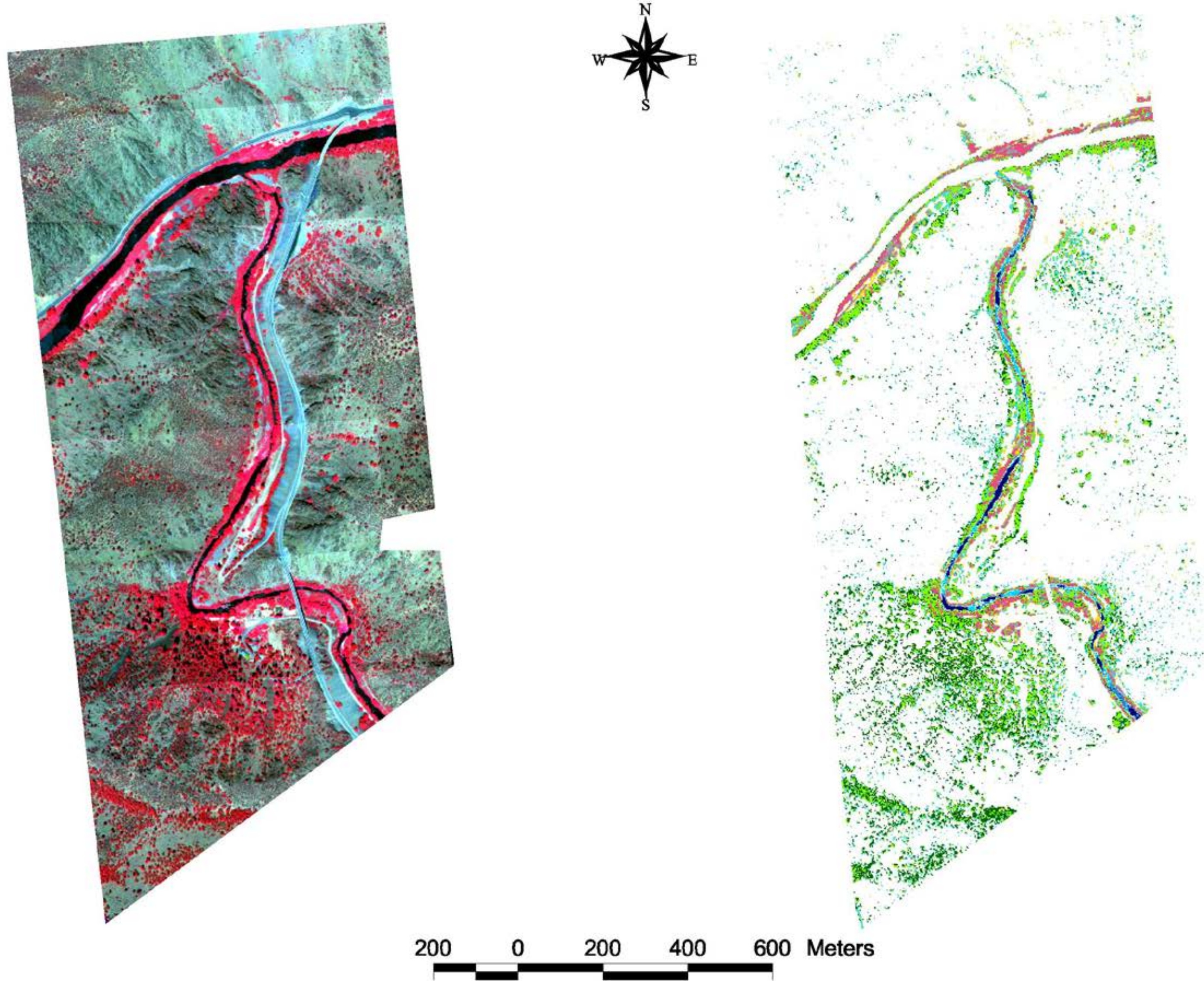

Figure A2. Shas0a orthophoto (left) and classified image (right)

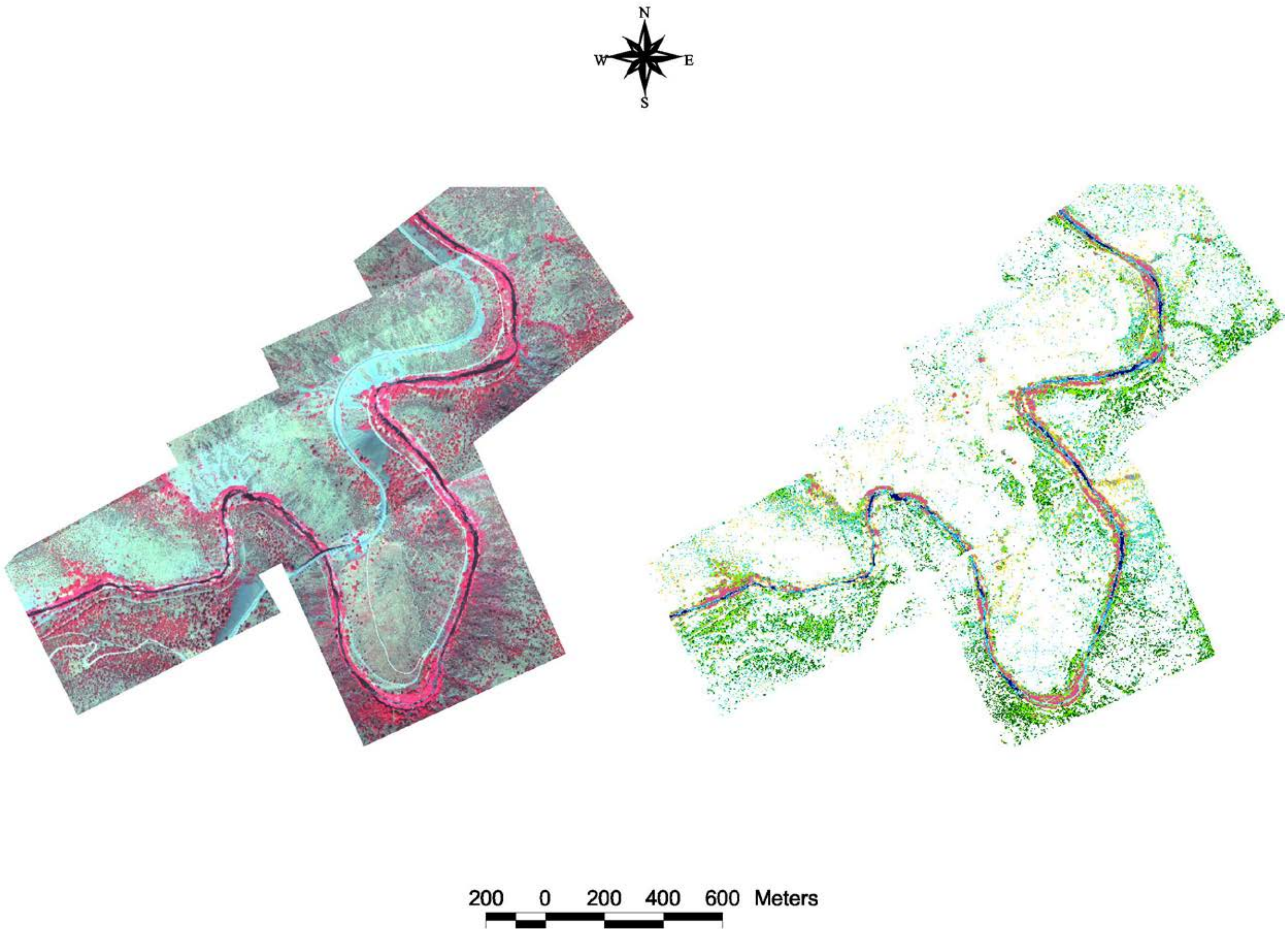

Figure A3. Shas0cd orthophoto (left) and classified image (right)

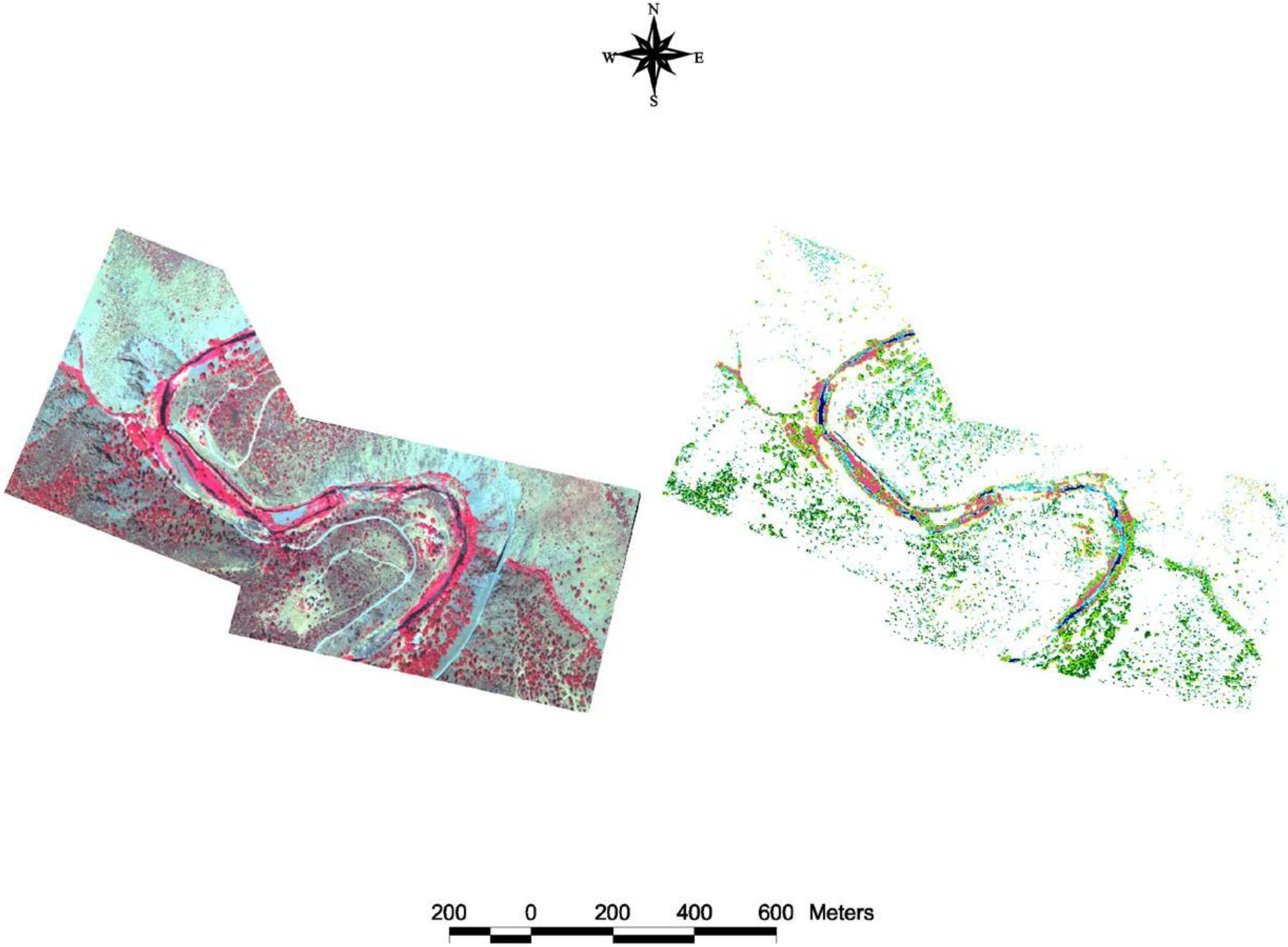

Figure A4. Shas0f orthophoto (left) and classified image (right)

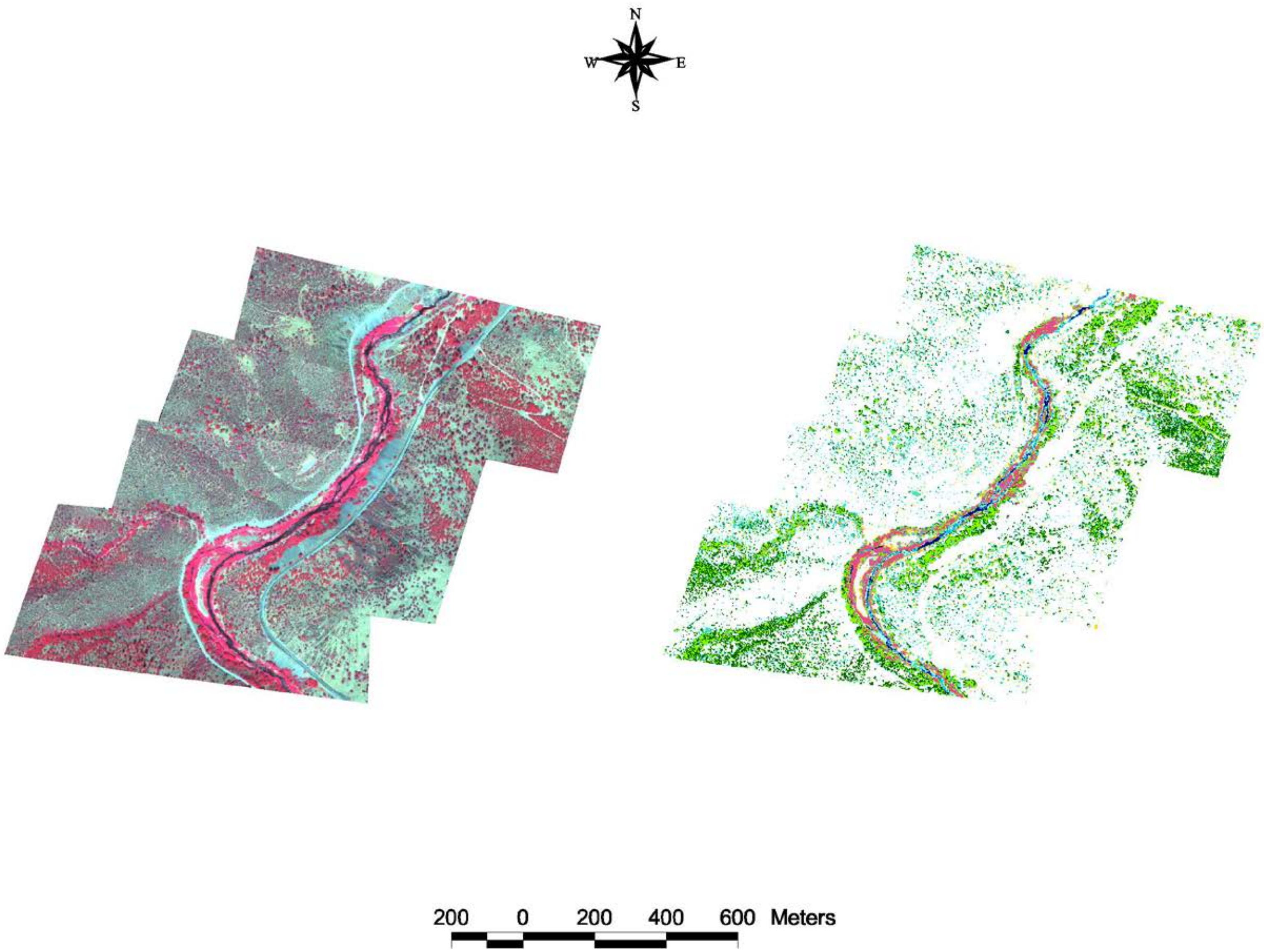

Figure A5. Shas0g orthophoto (left) and classified image (right)

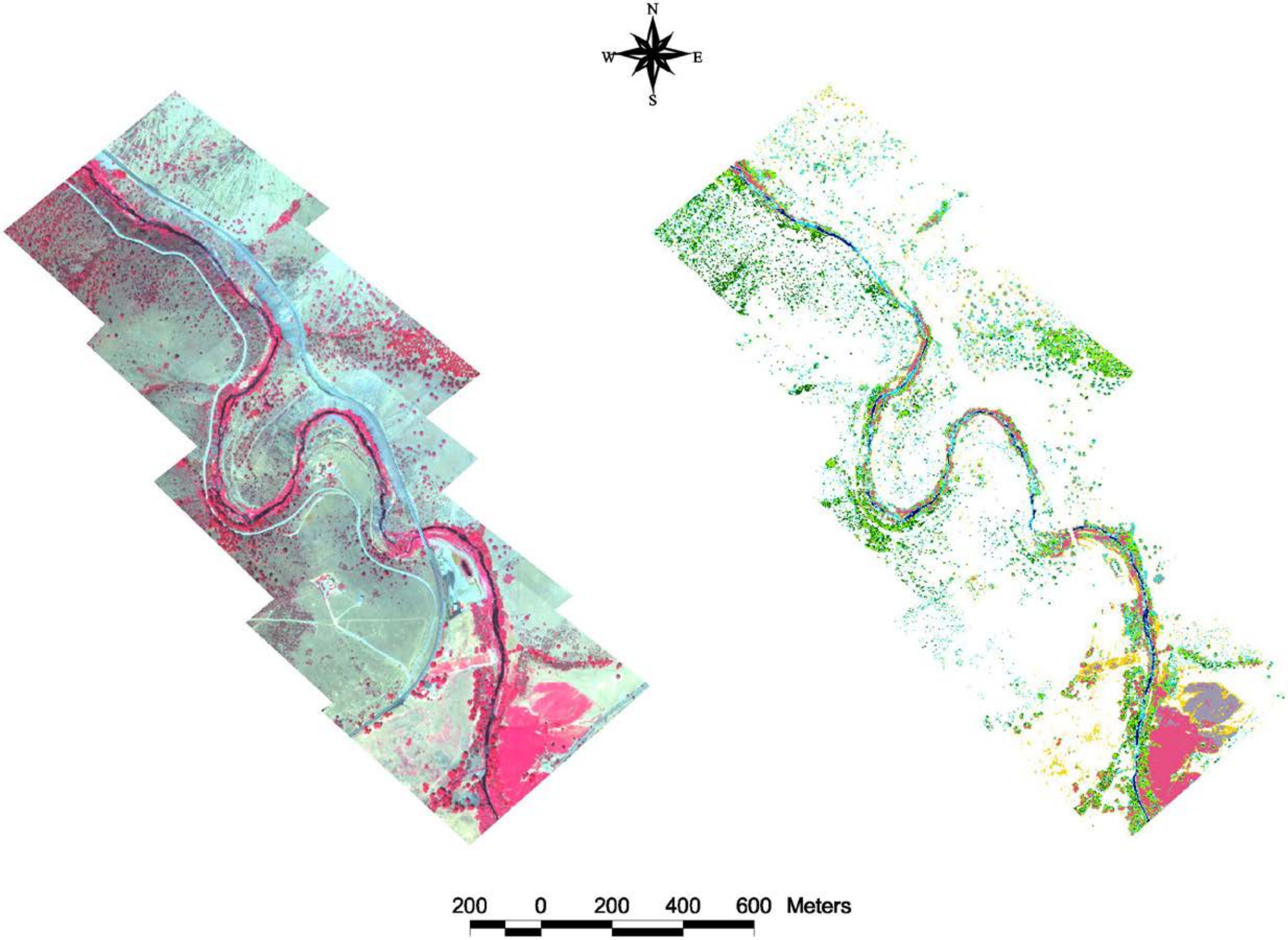

Figure A6. Shas0h orthophoto (left) and classified image (right)

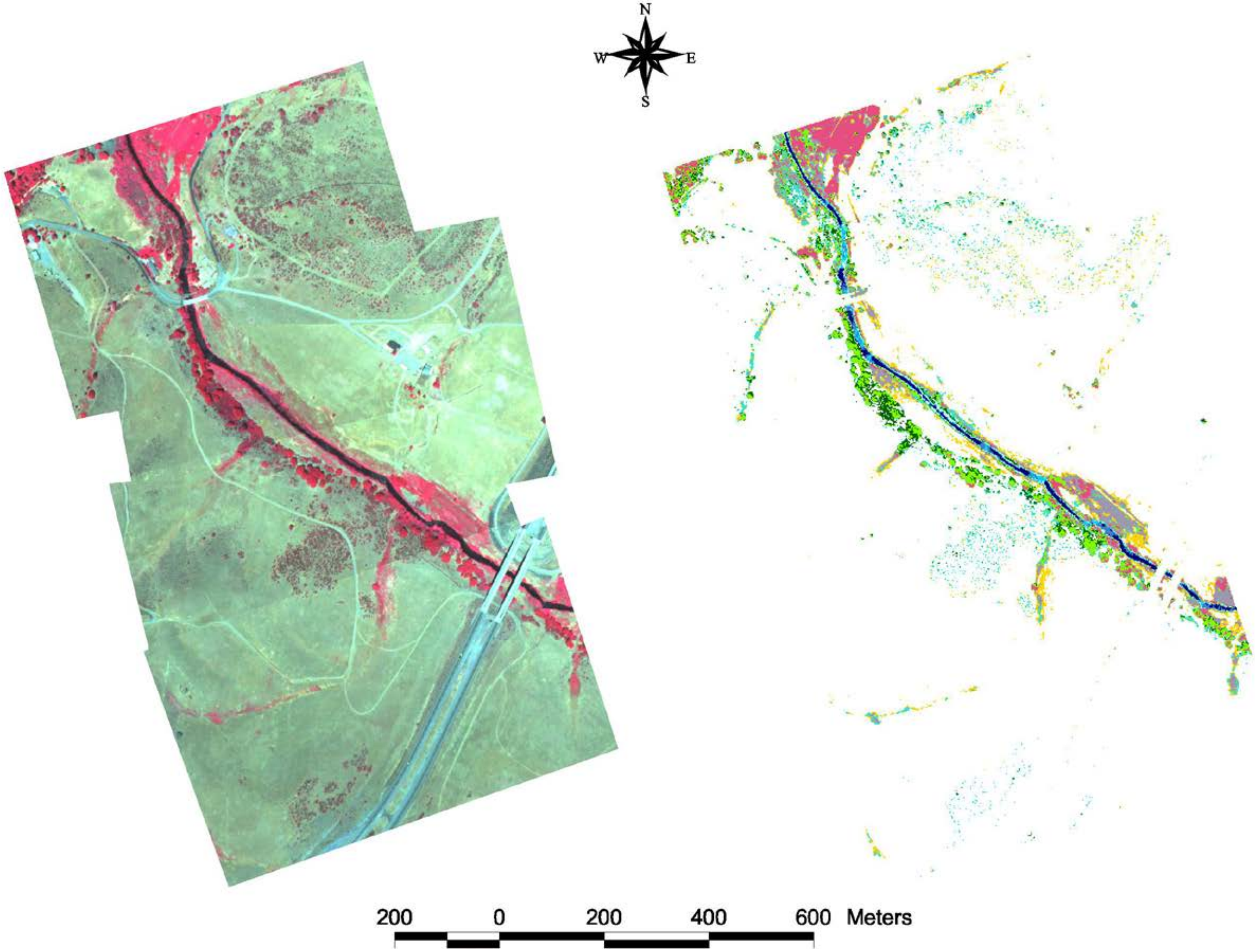

Figure A7. Shas0j orthophoto (left) and classified image (right)

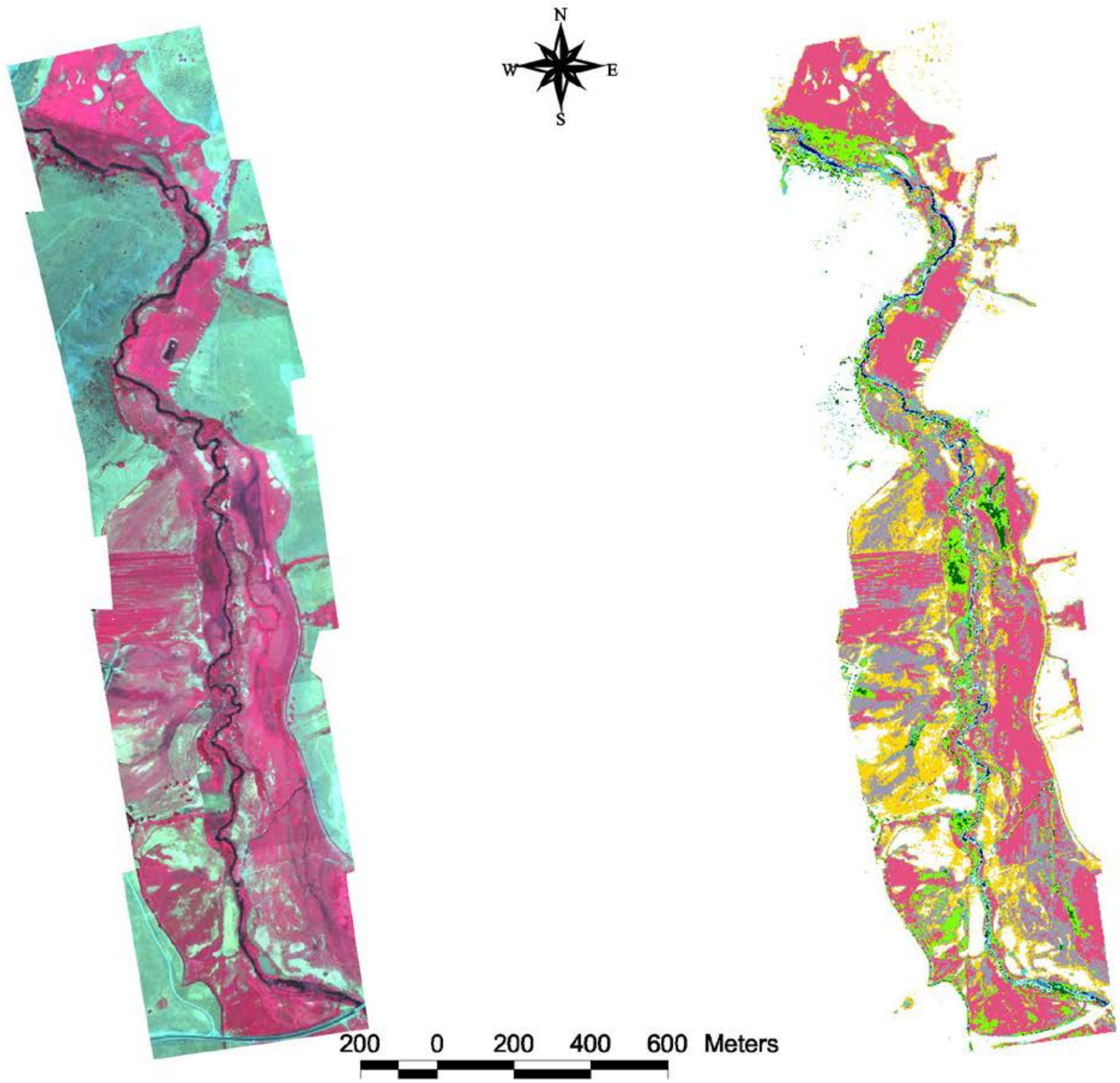

Figure A8. Shas0l orthophoto (left) and classified image (right)

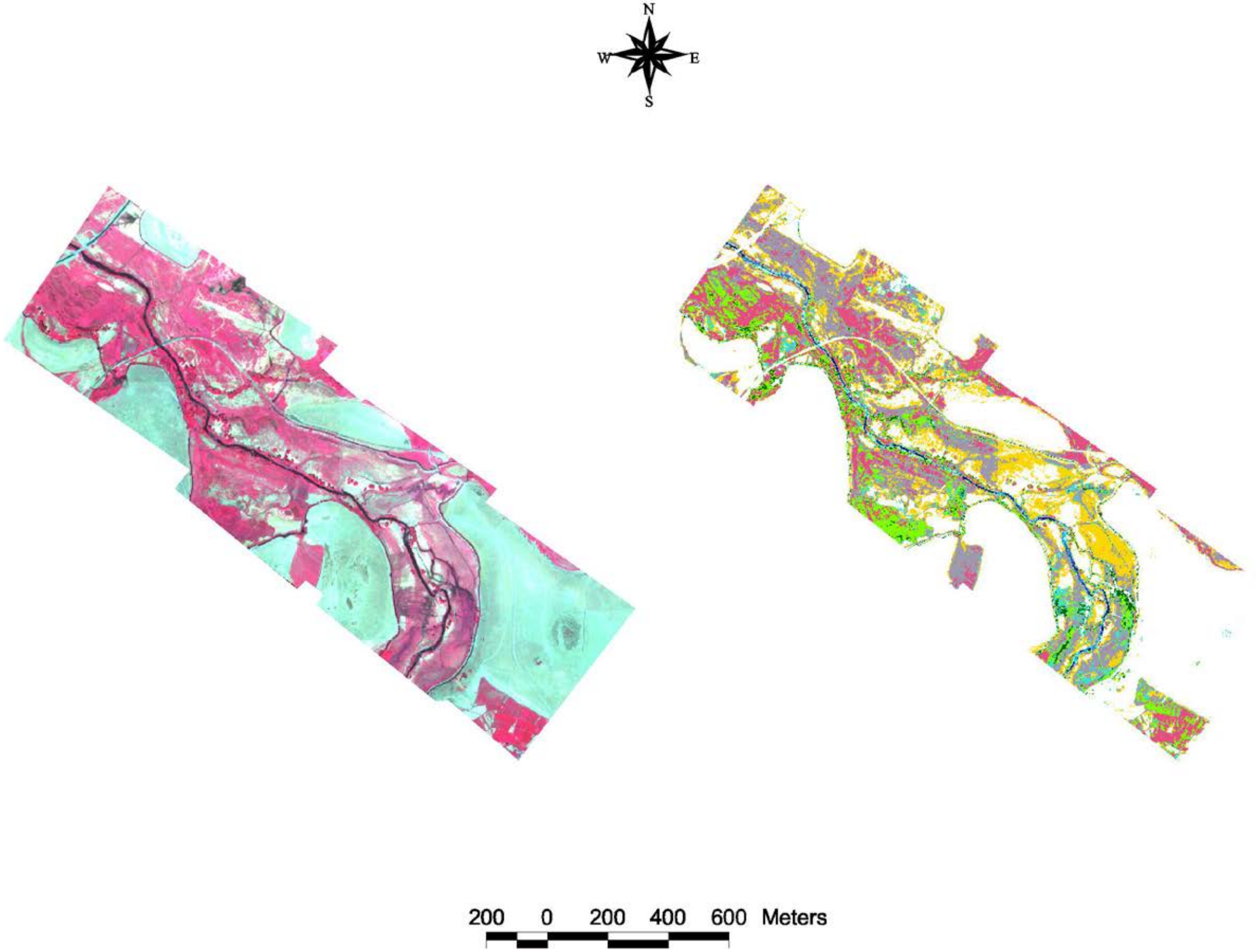

Figure A9. Shas0m orthophoto (left) and classified image (right)

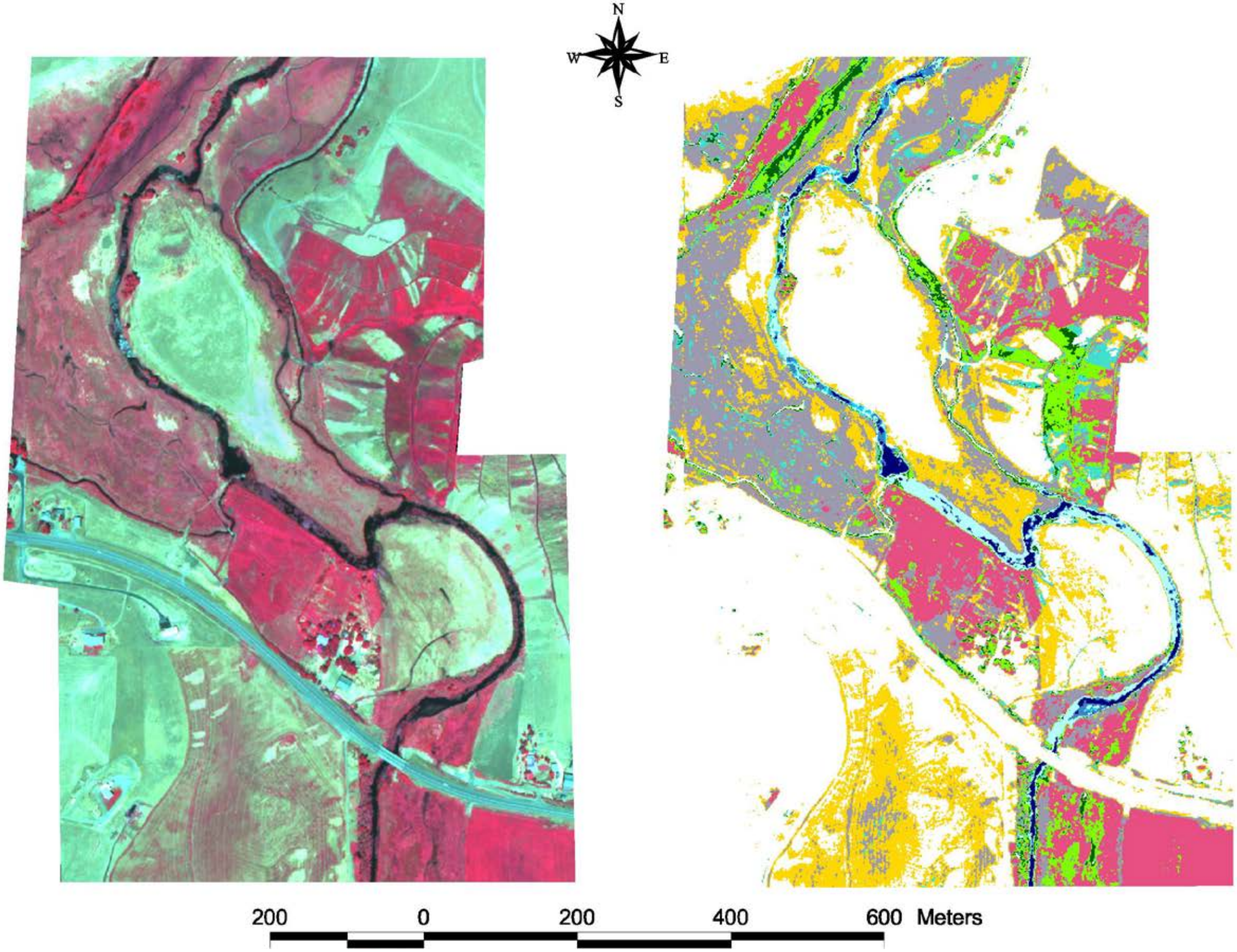

Figure A10. Shas0n orthophoto (left) and classified image (right)

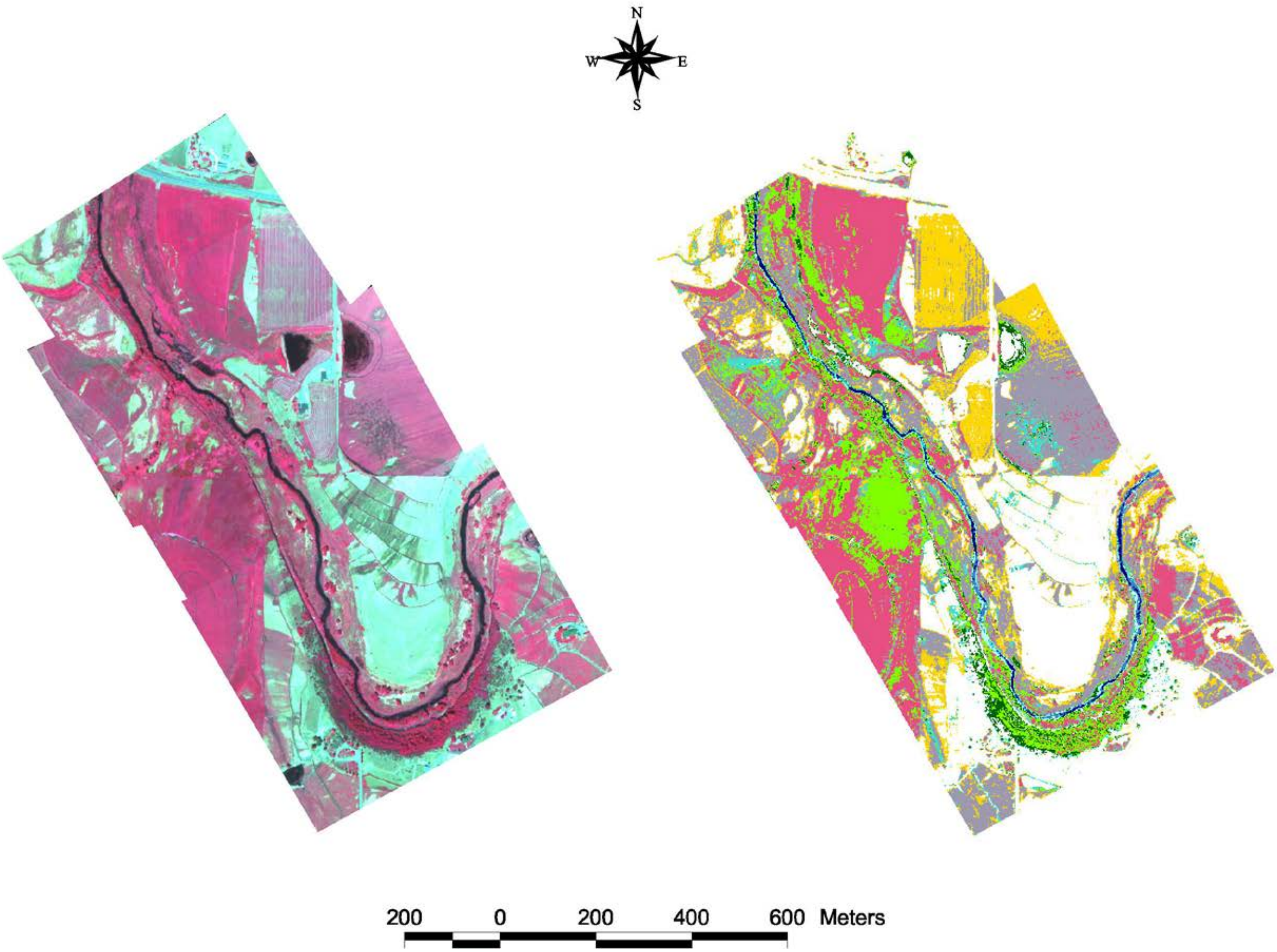

Figure A11. Shas0o orthophoto (left) and classified image (right)

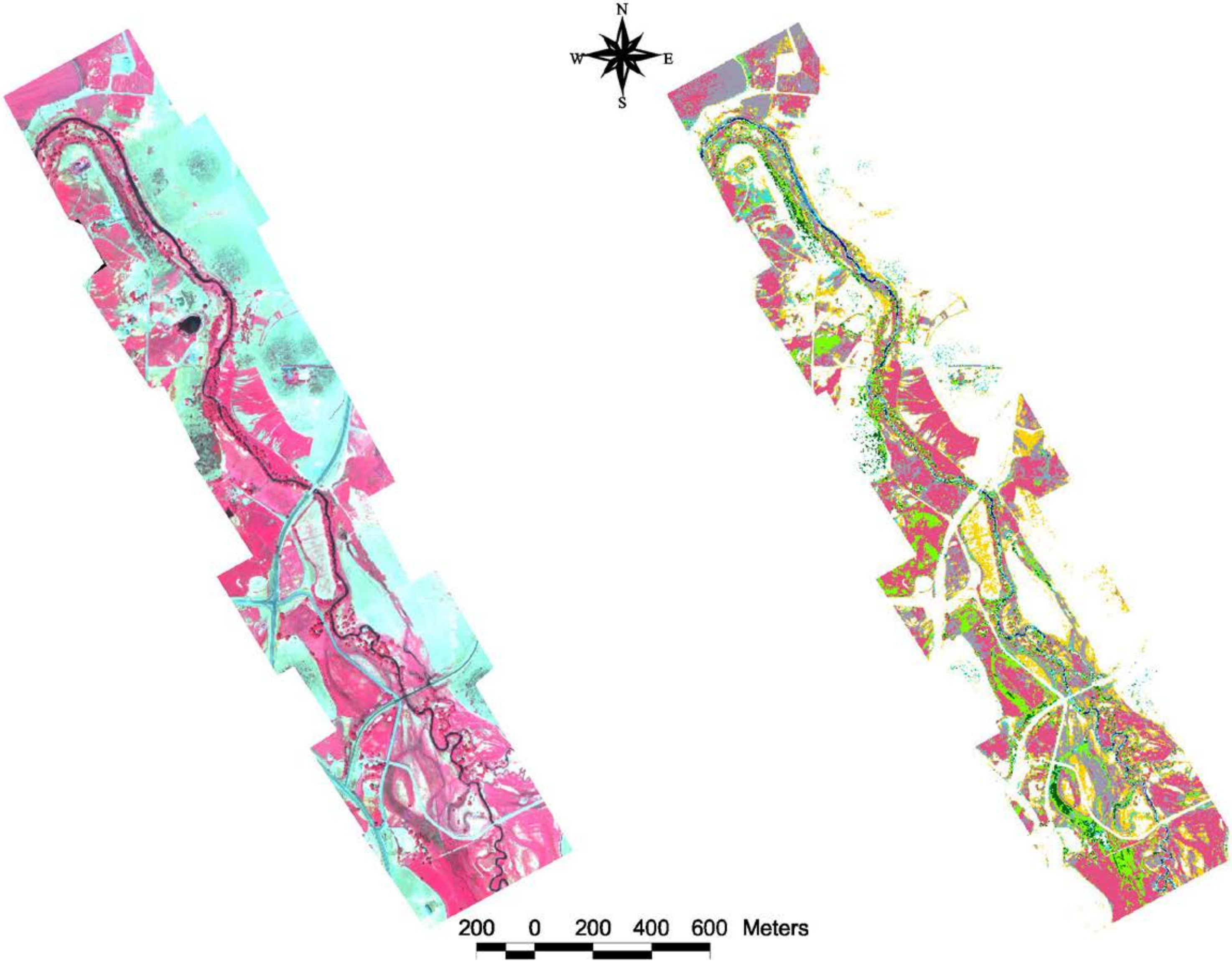

Figure A12. Shas0q orthophoto (left) and classified image (right)

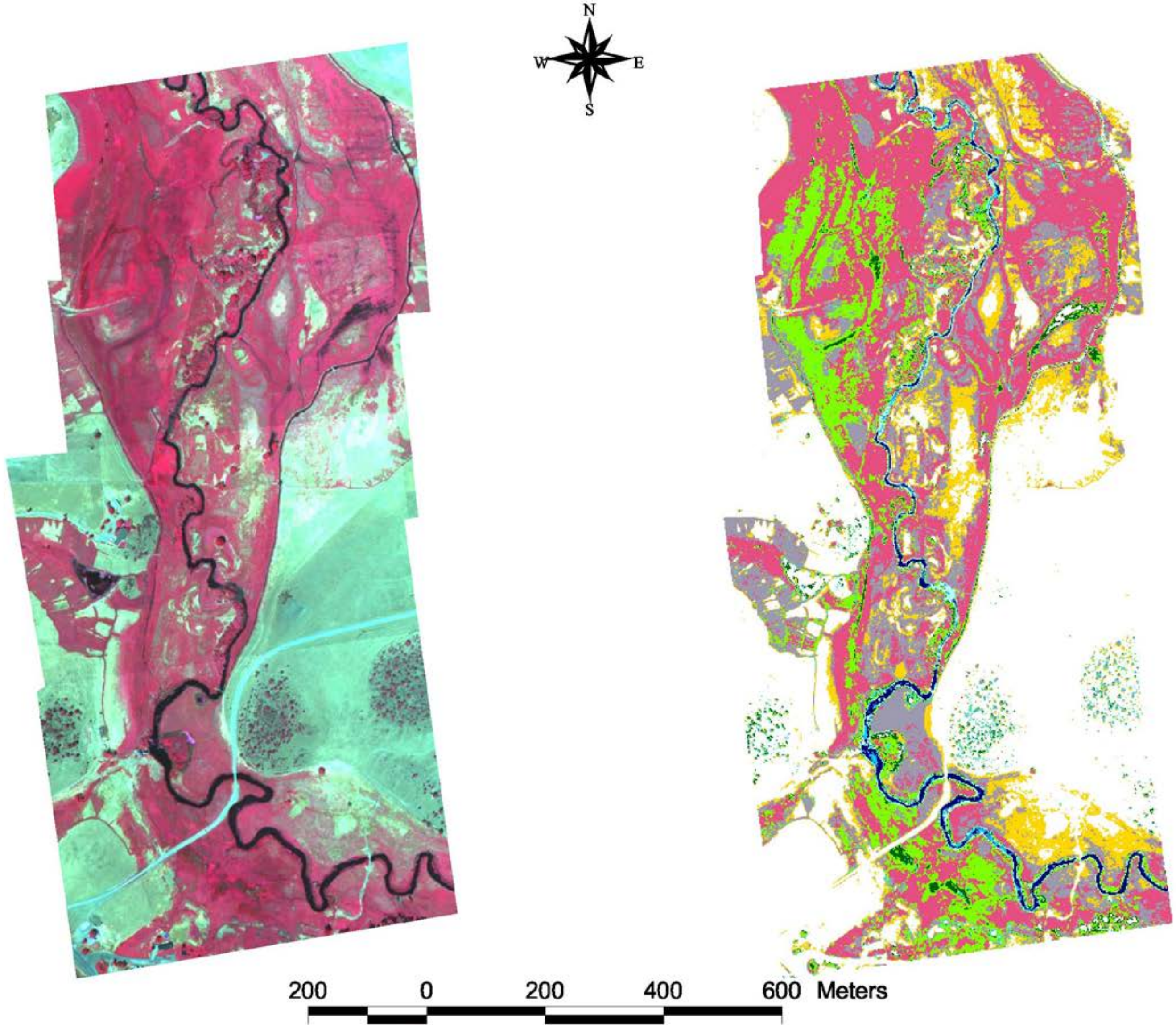

Figure A13. Shas0r orthophoto (left) and classified image (right)

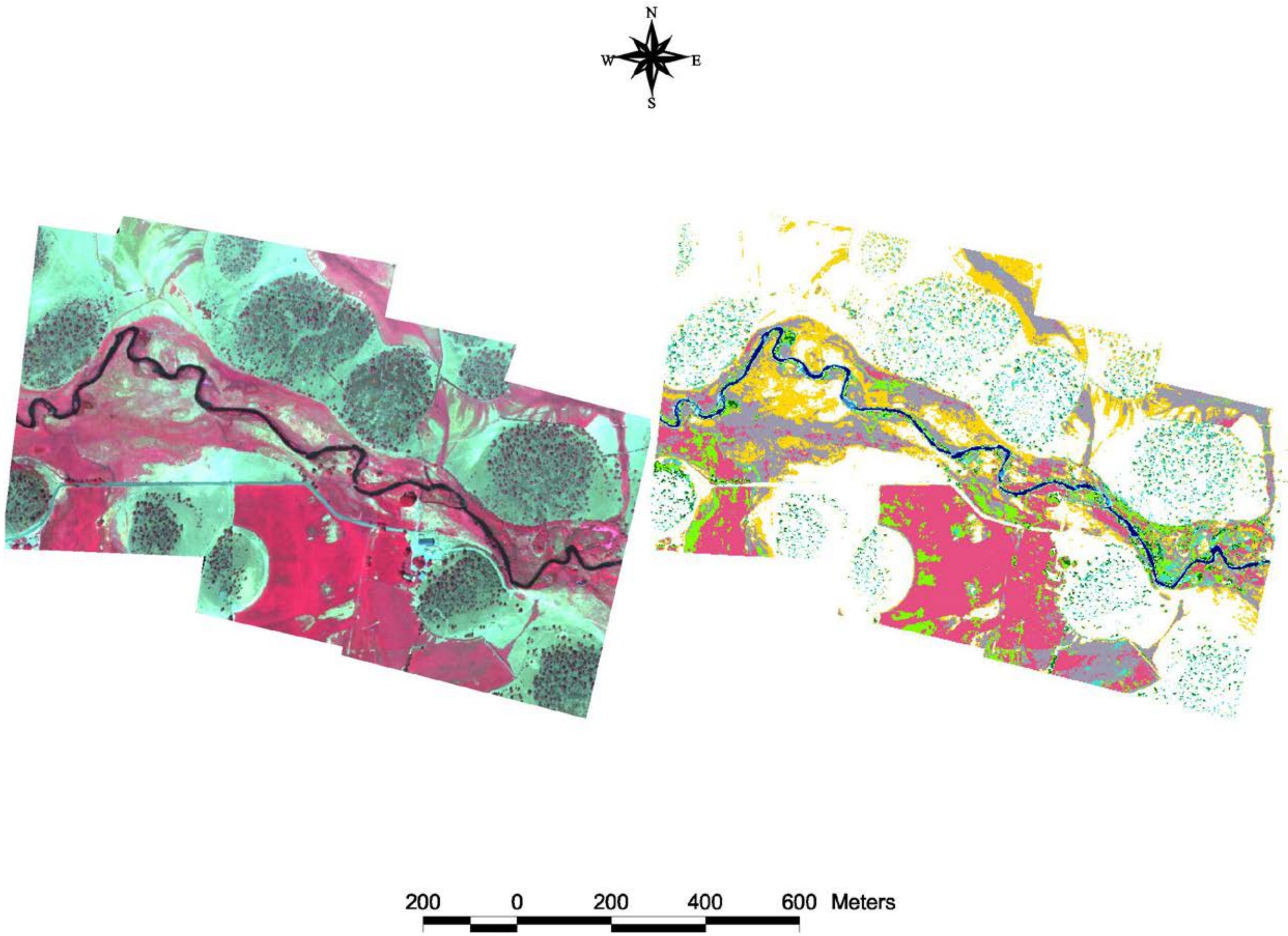

Figure A14. Shas0s orthophoto (left) and classified image (right)

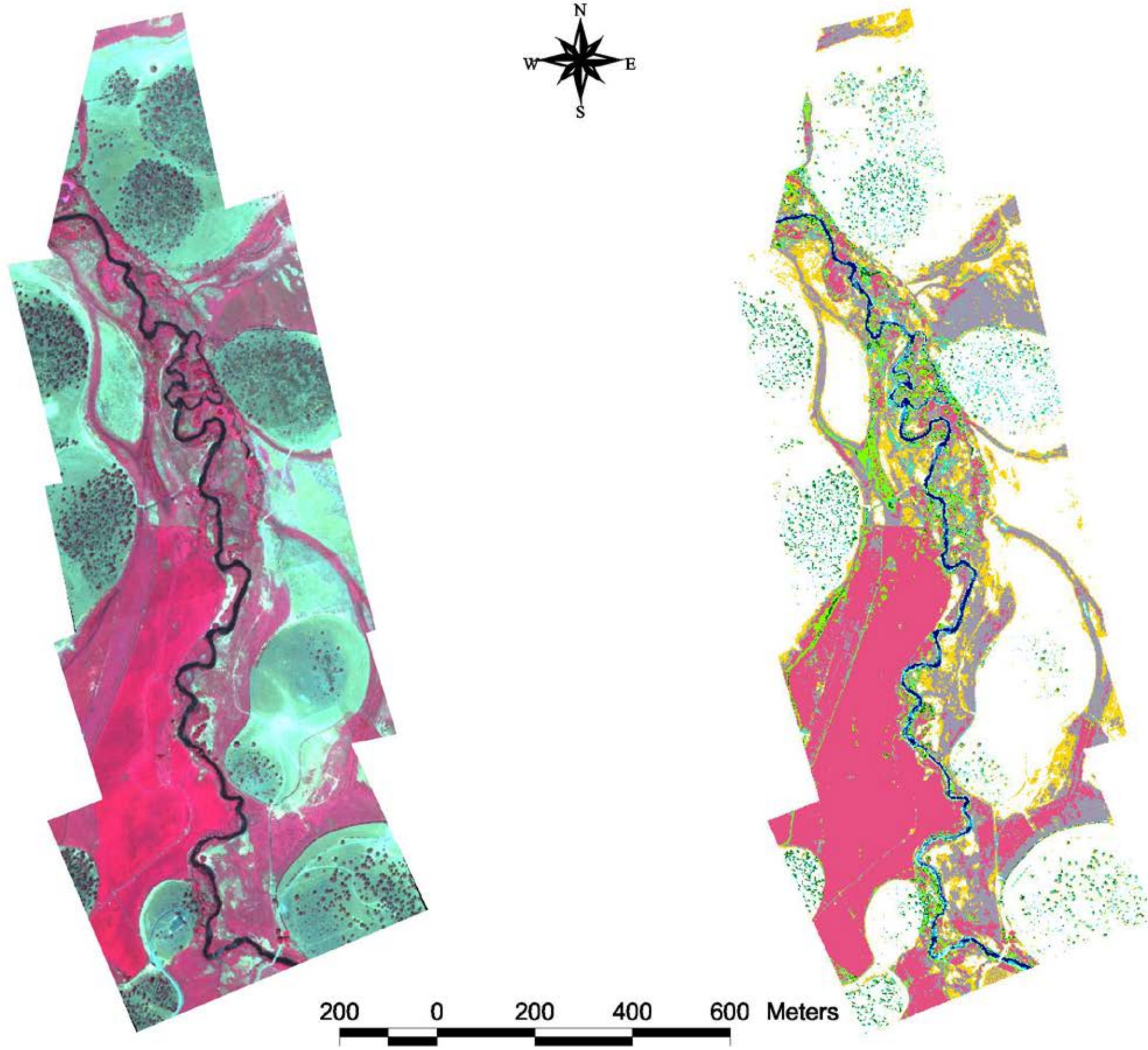

Figure A15. Shas0t orthophoto (left) and classified image (right)

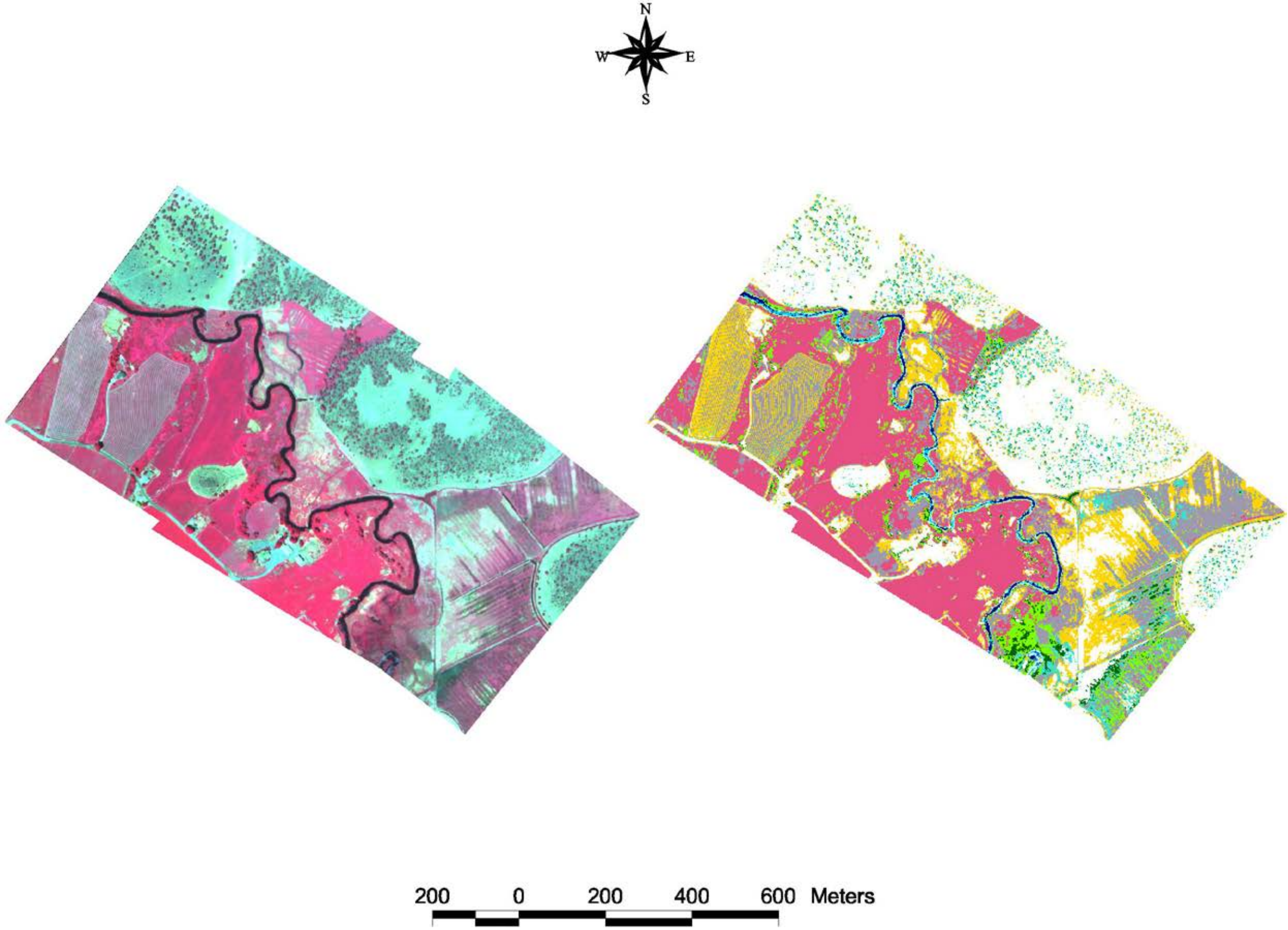

Figure A16. Shas0u orthophoto (left) and classified image (right)

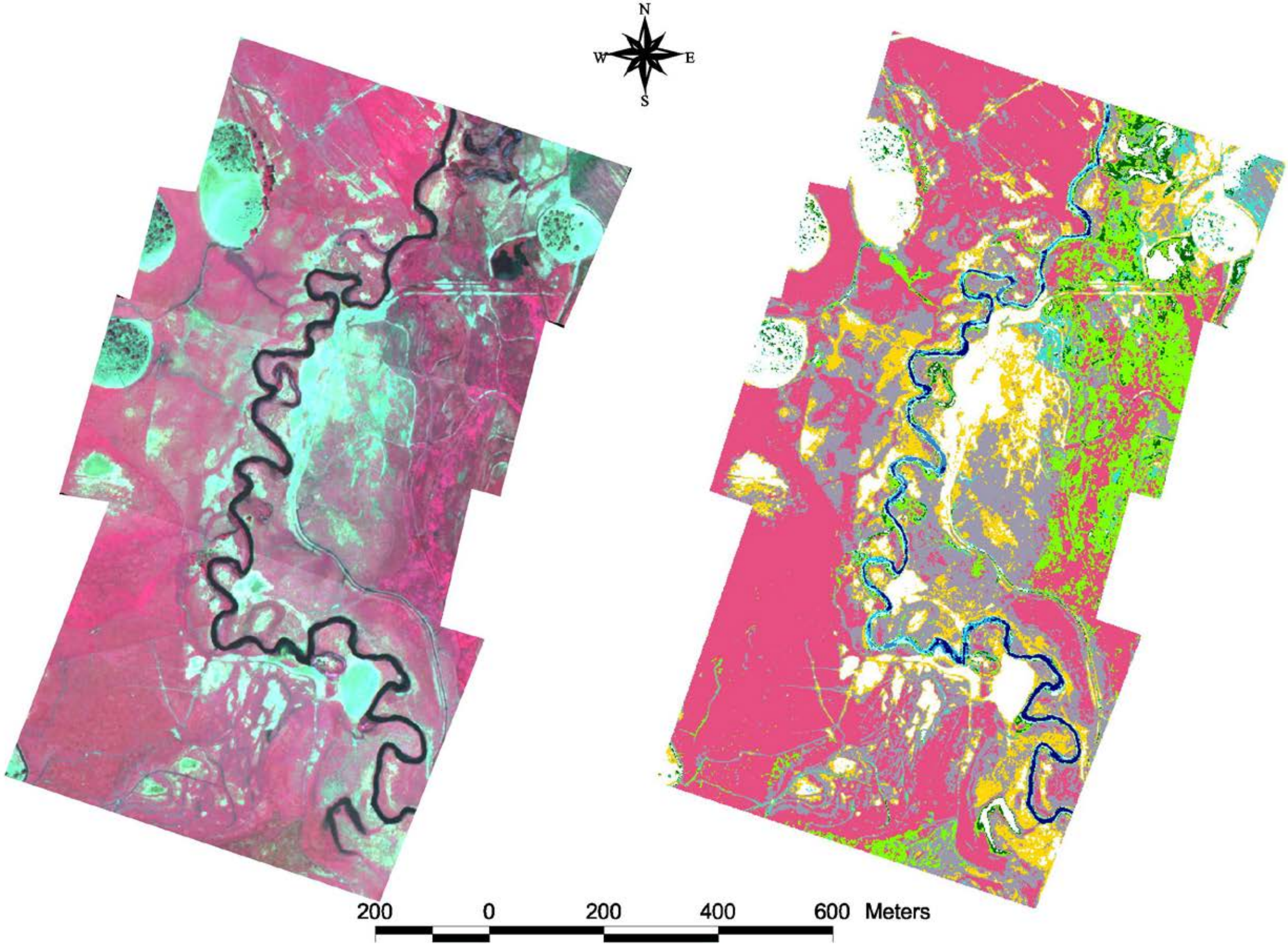

Figure A17. Shas0v orthophoto (left) and classified image (right)

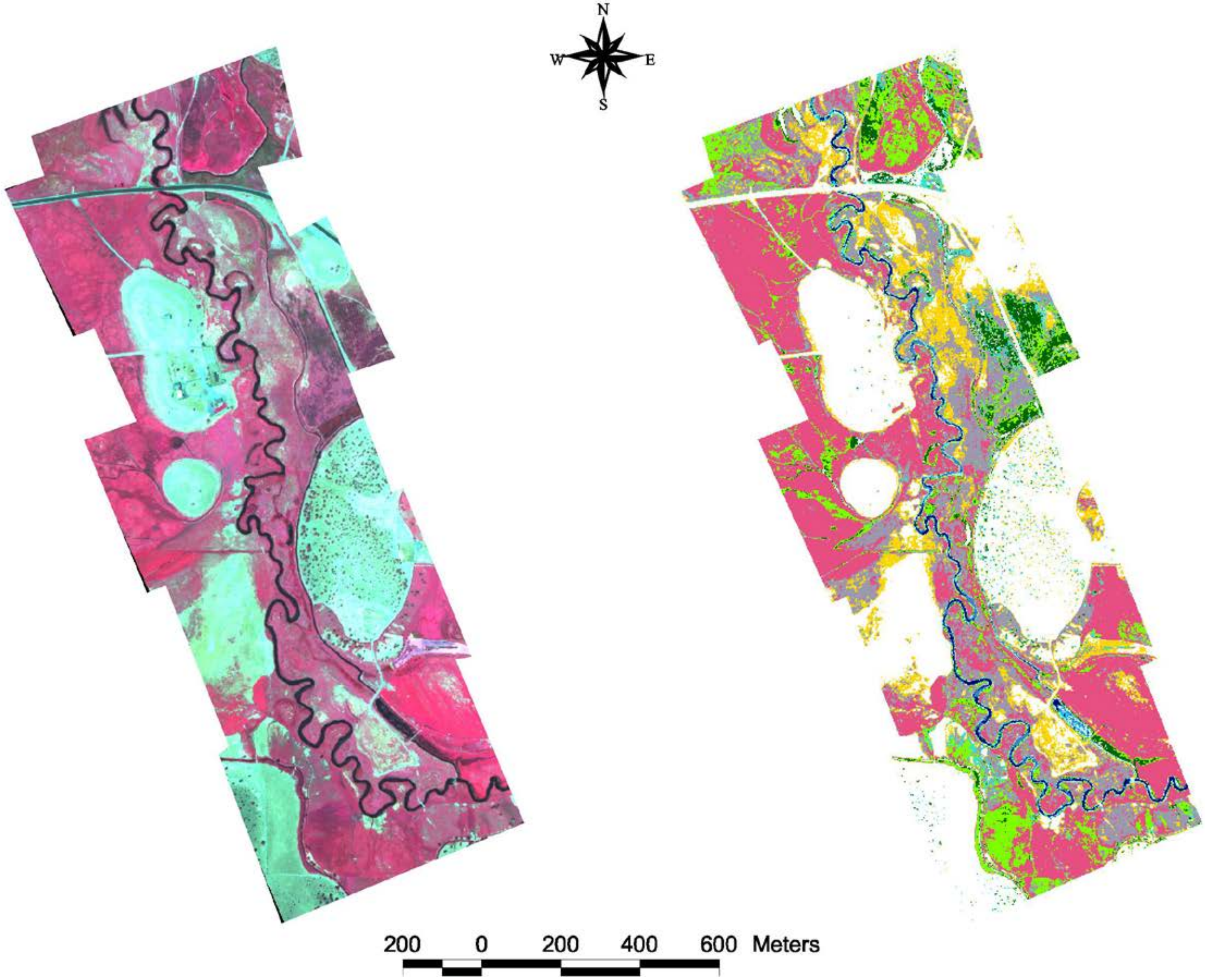

Figure A18. Shas0w orthophoto (left) and classified image (right)

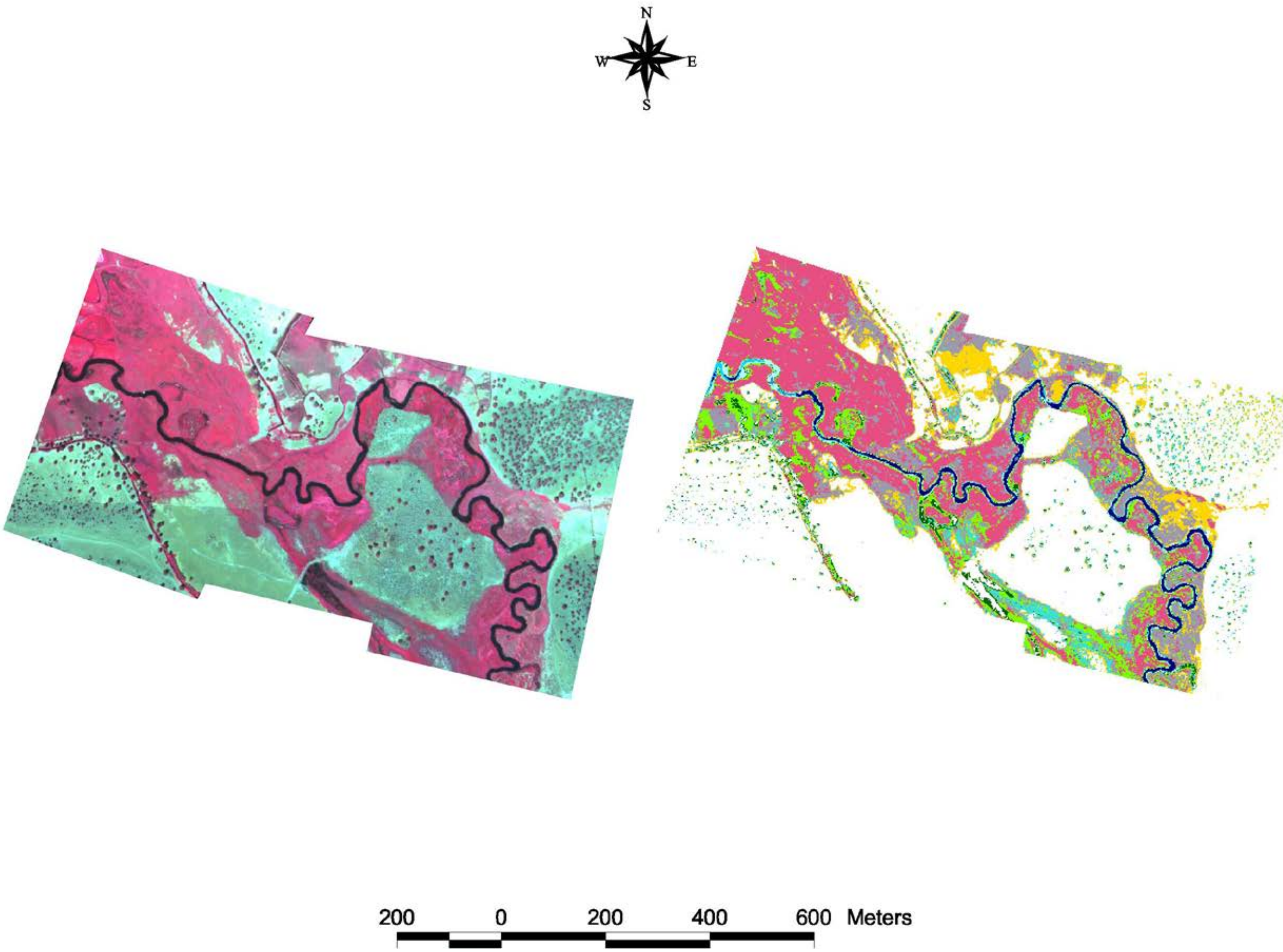

Figure A19. Shas0x orthophoto (left) and classified image (right)

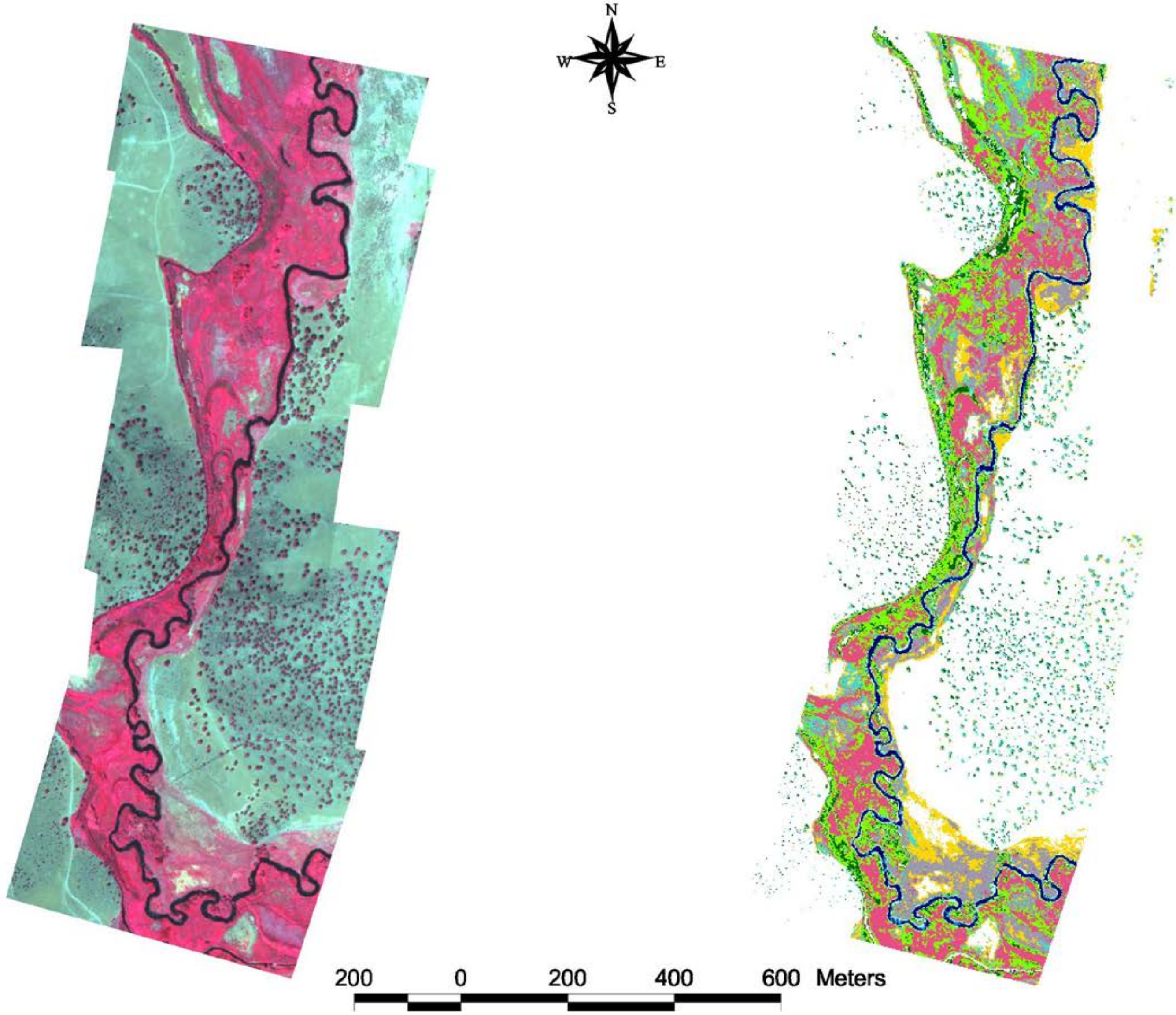

Figure A20. Shas0y orthophoto (left) and classified image (right)

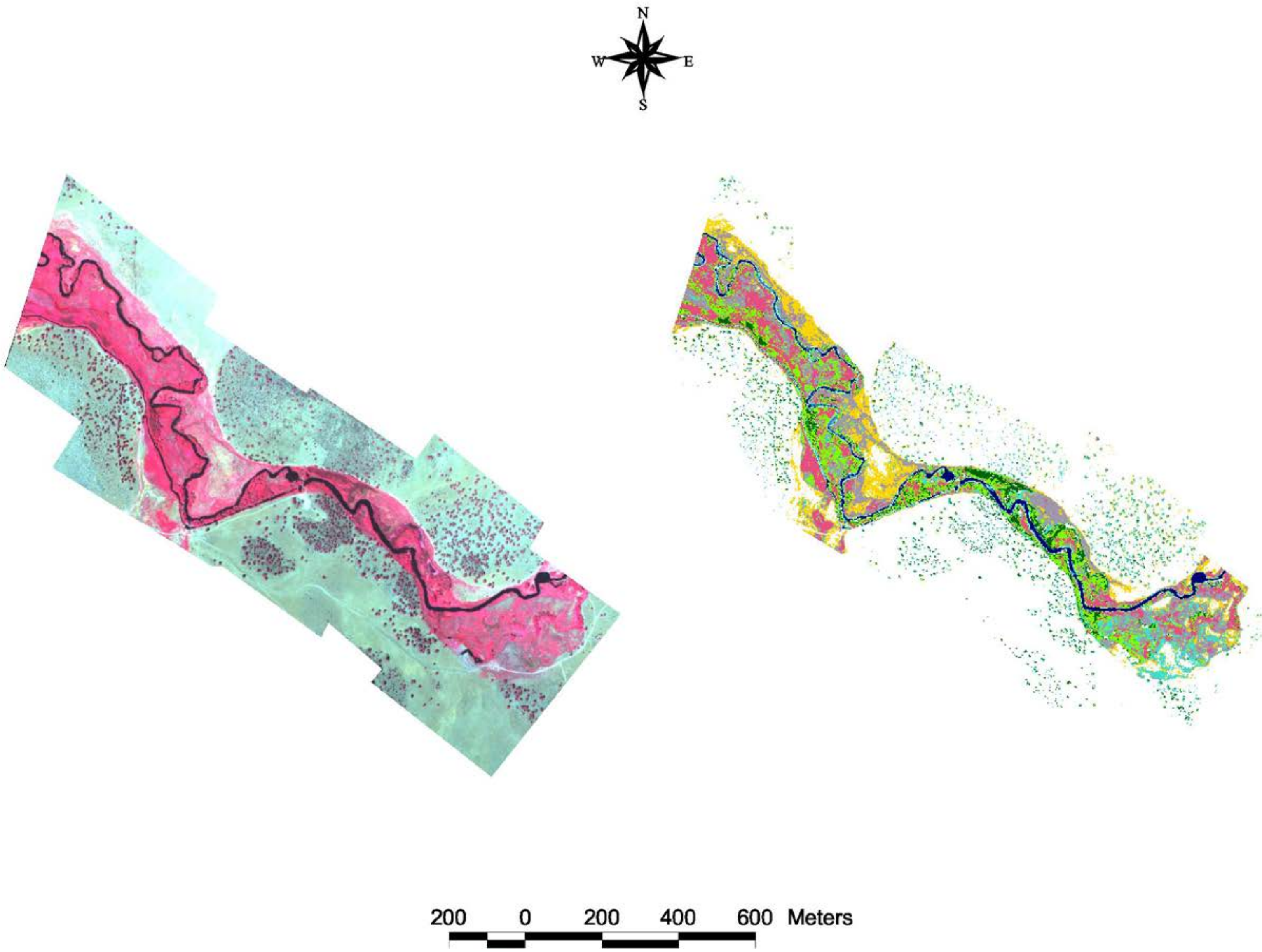

Figure A21. Shas0z orthophoto (left) and classified image (right)

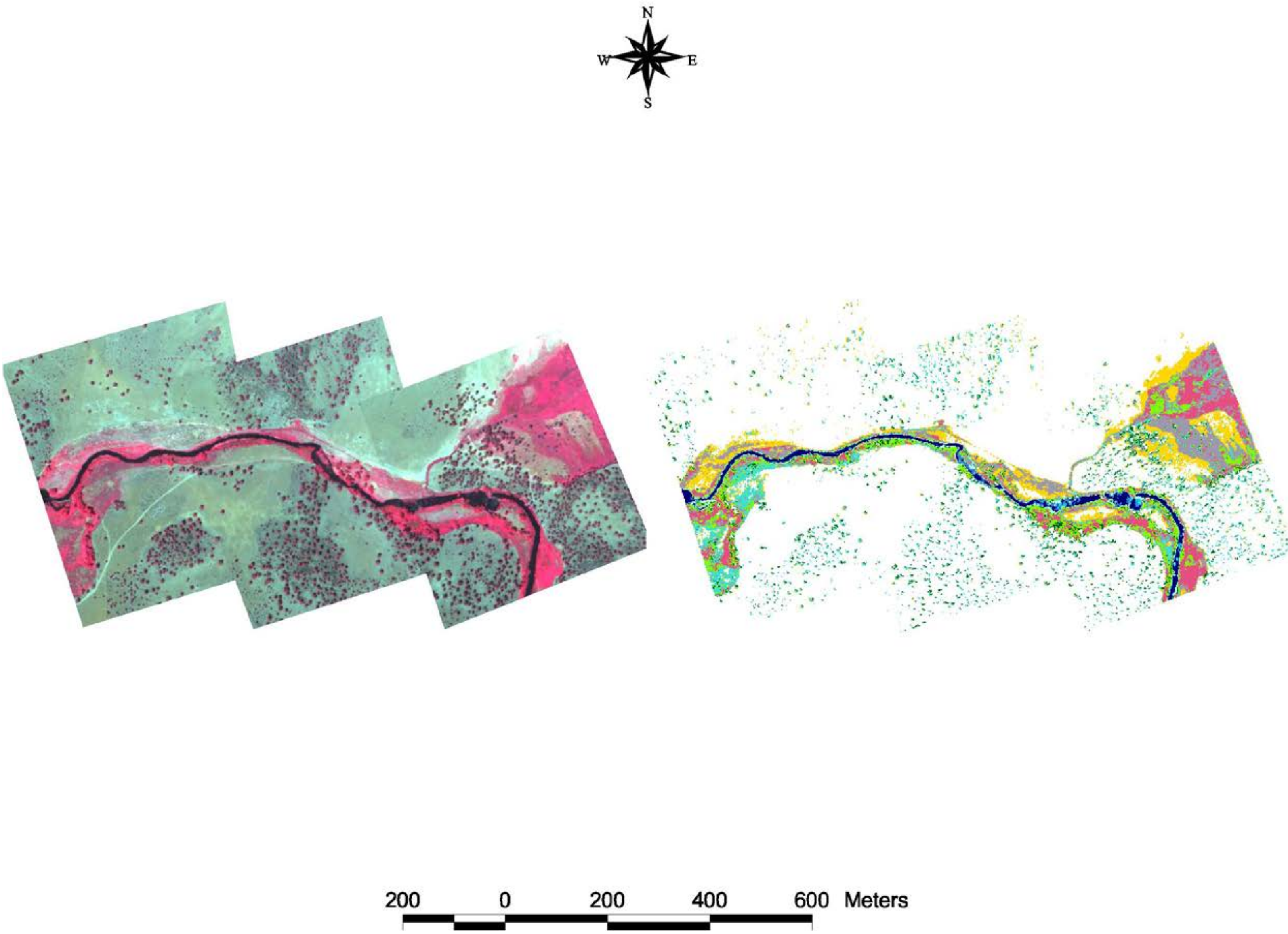

Figure A22. Shas1a orthophoto (left) and classified image (right)

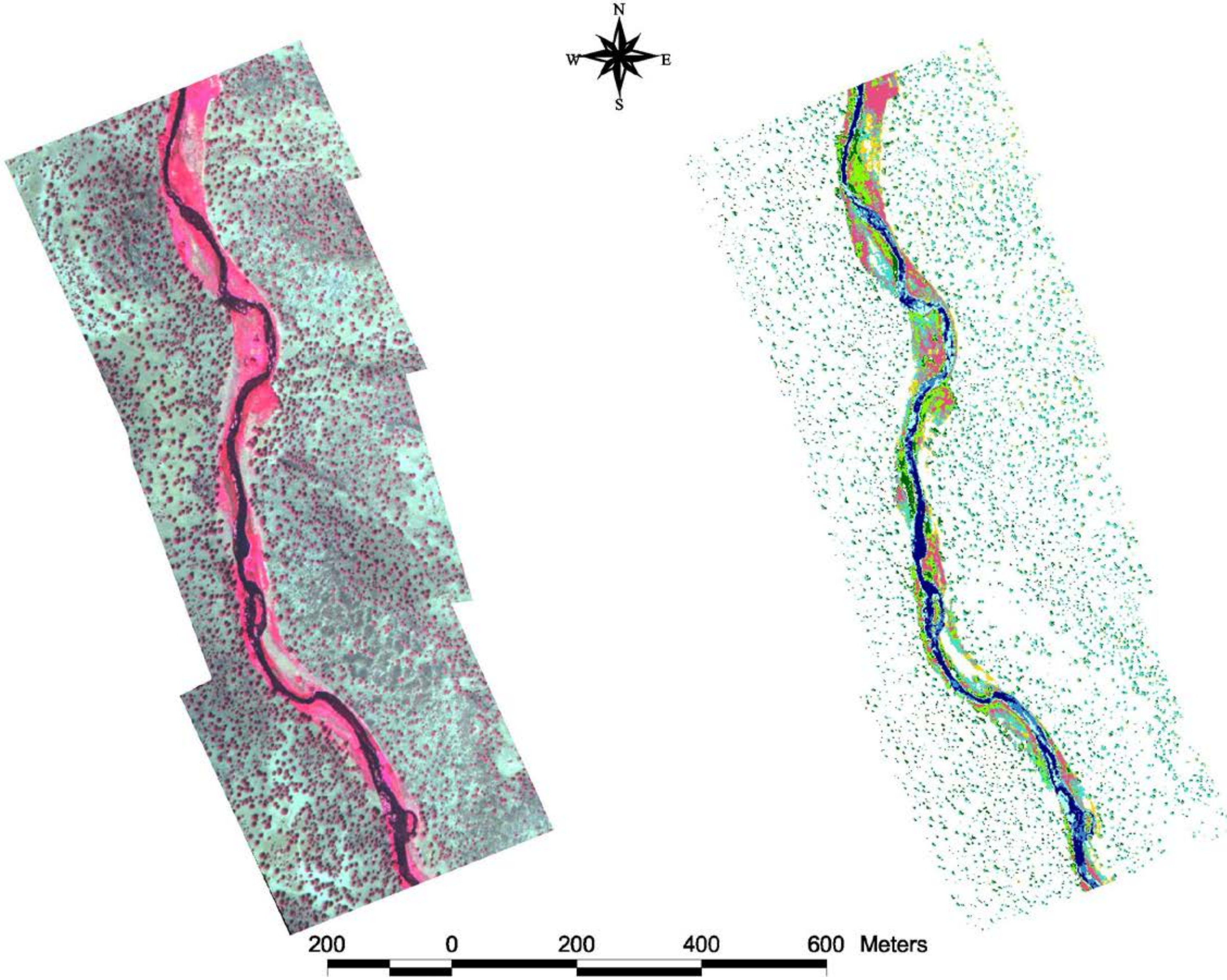

Figure A23. Shas1b orthophoto (left) and classified image (right)

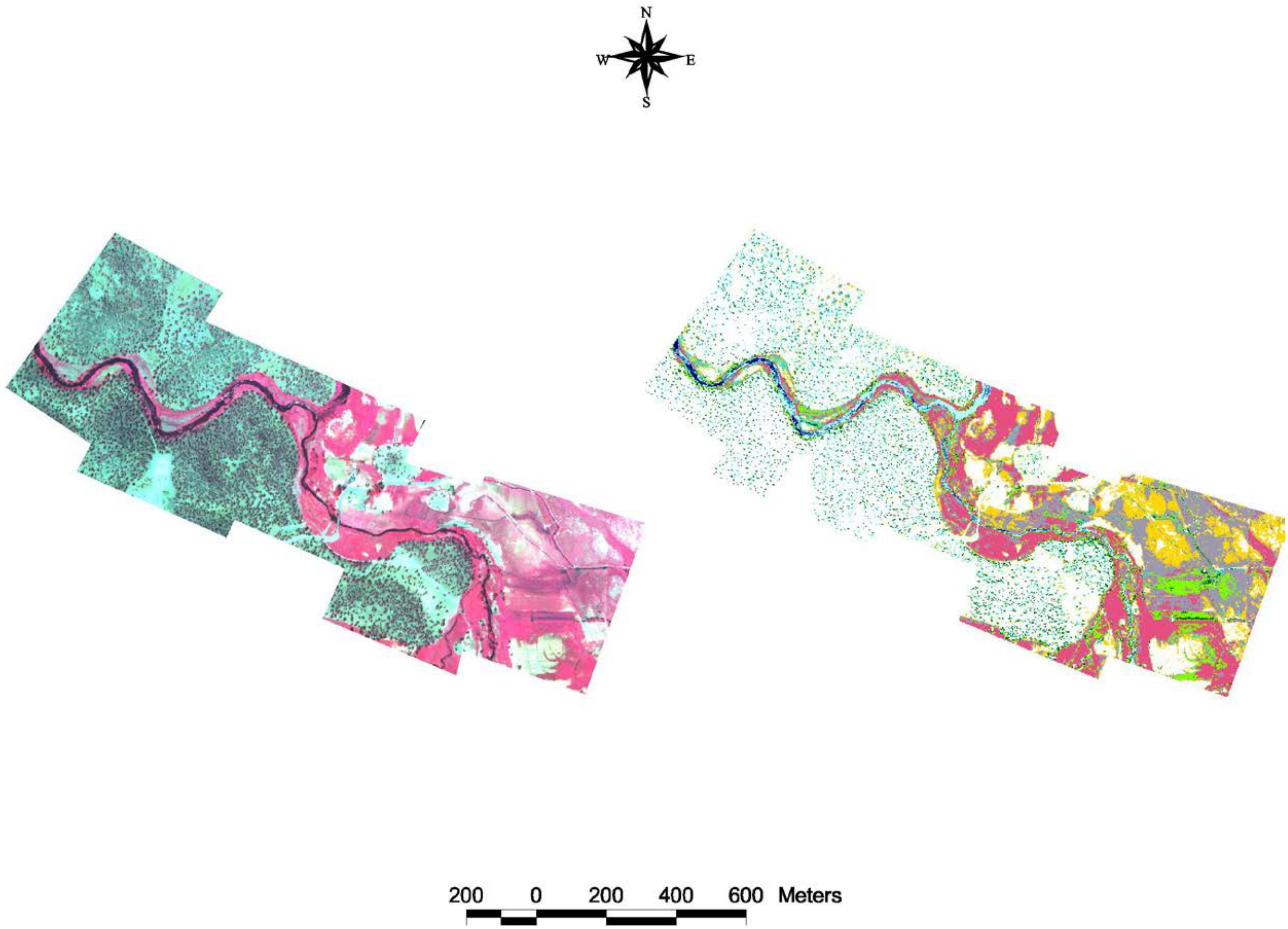

Figure A24. Shas1c orthophoto (left) and classified image (right)

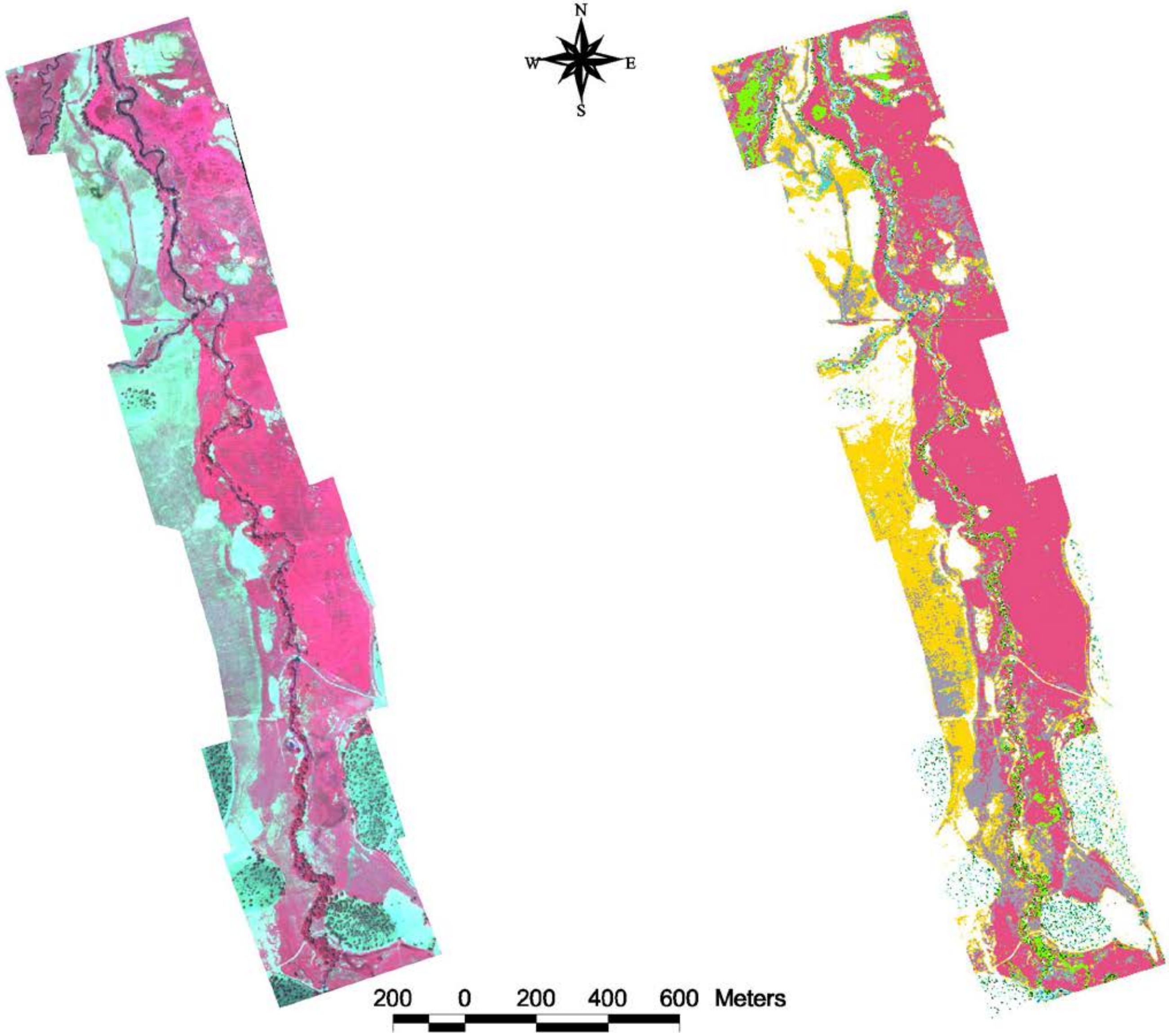

Figure A25. Shas1d orthophoto (left) and classified image (right)

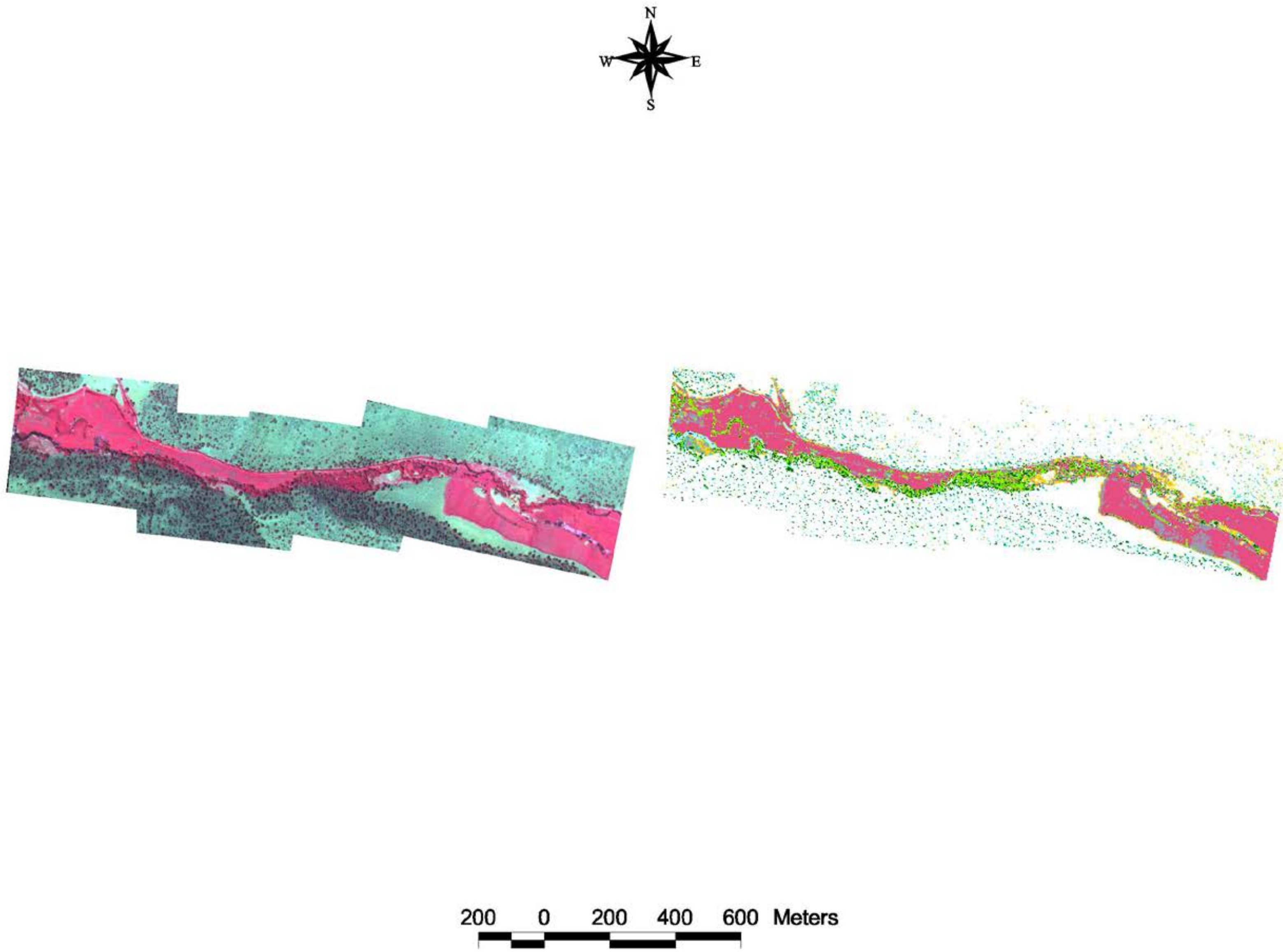

Figure A26. Shas1e orthophoto (left) and classified image (right)

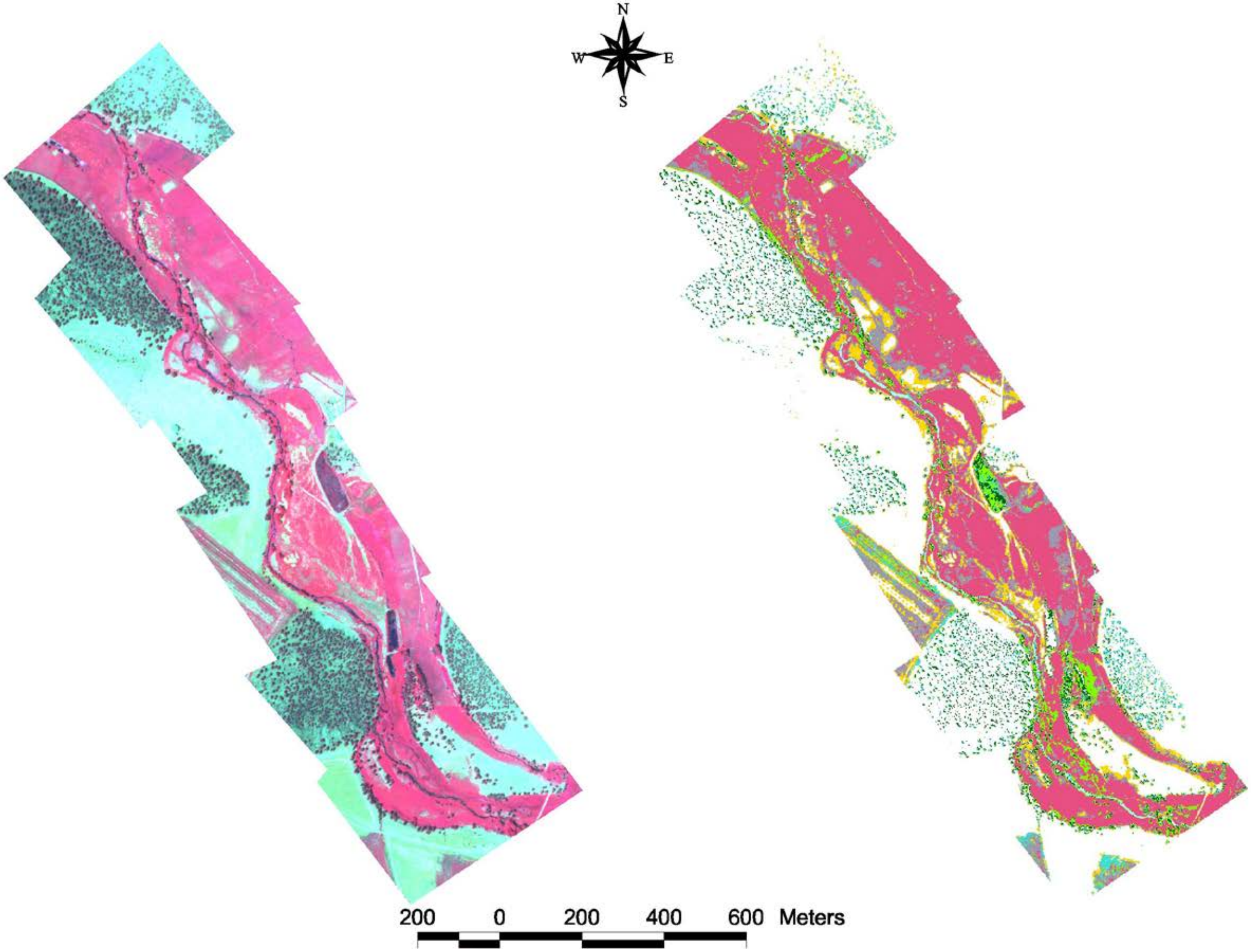

Figure A27. Shas1f orthophoto (left) and classified image (right)

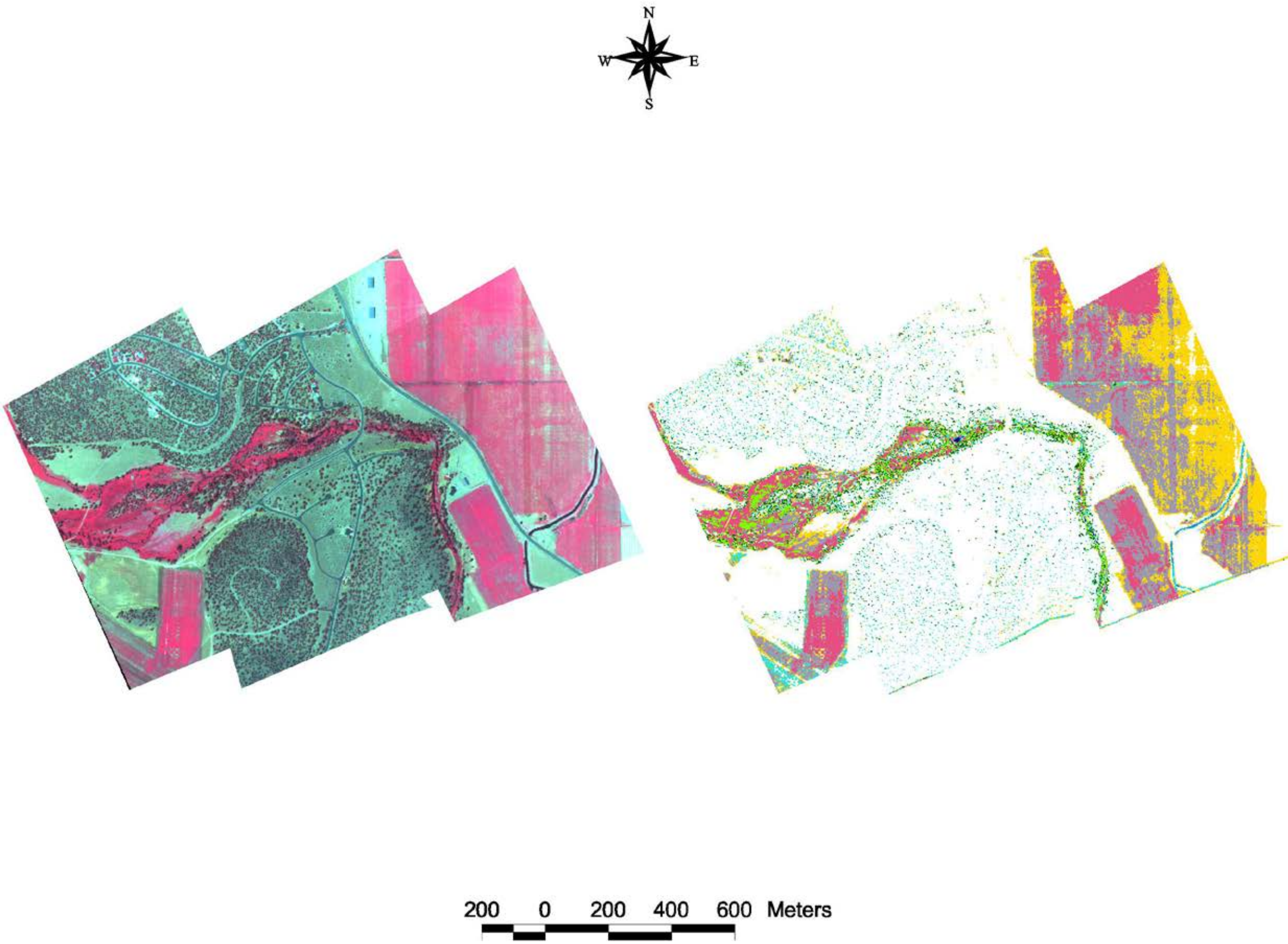

Figure A28. Shas1g orthophoto (left) and classified image (right)

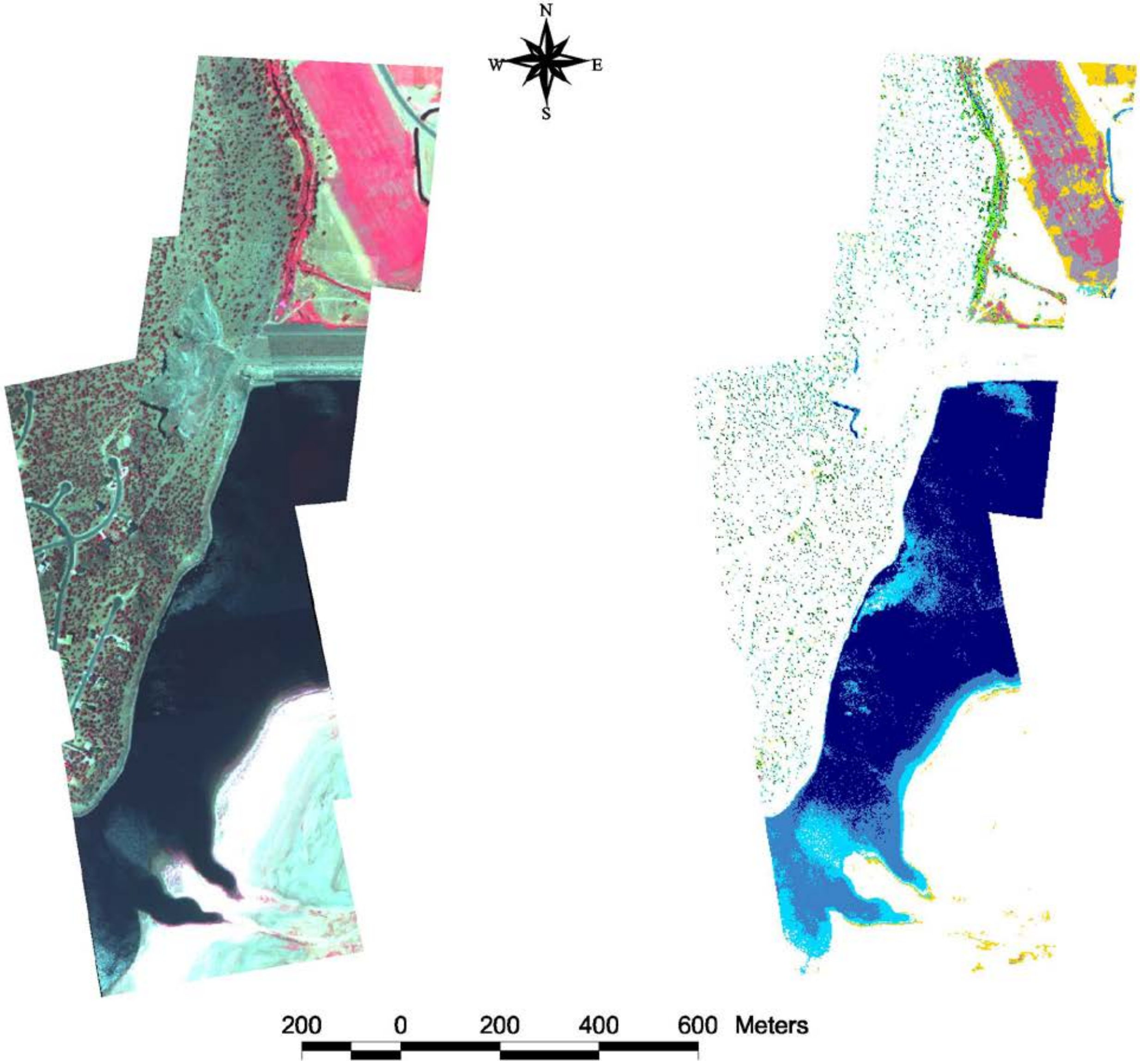

Figure A29. Shas1h orthophoto (left) and classified image (right)

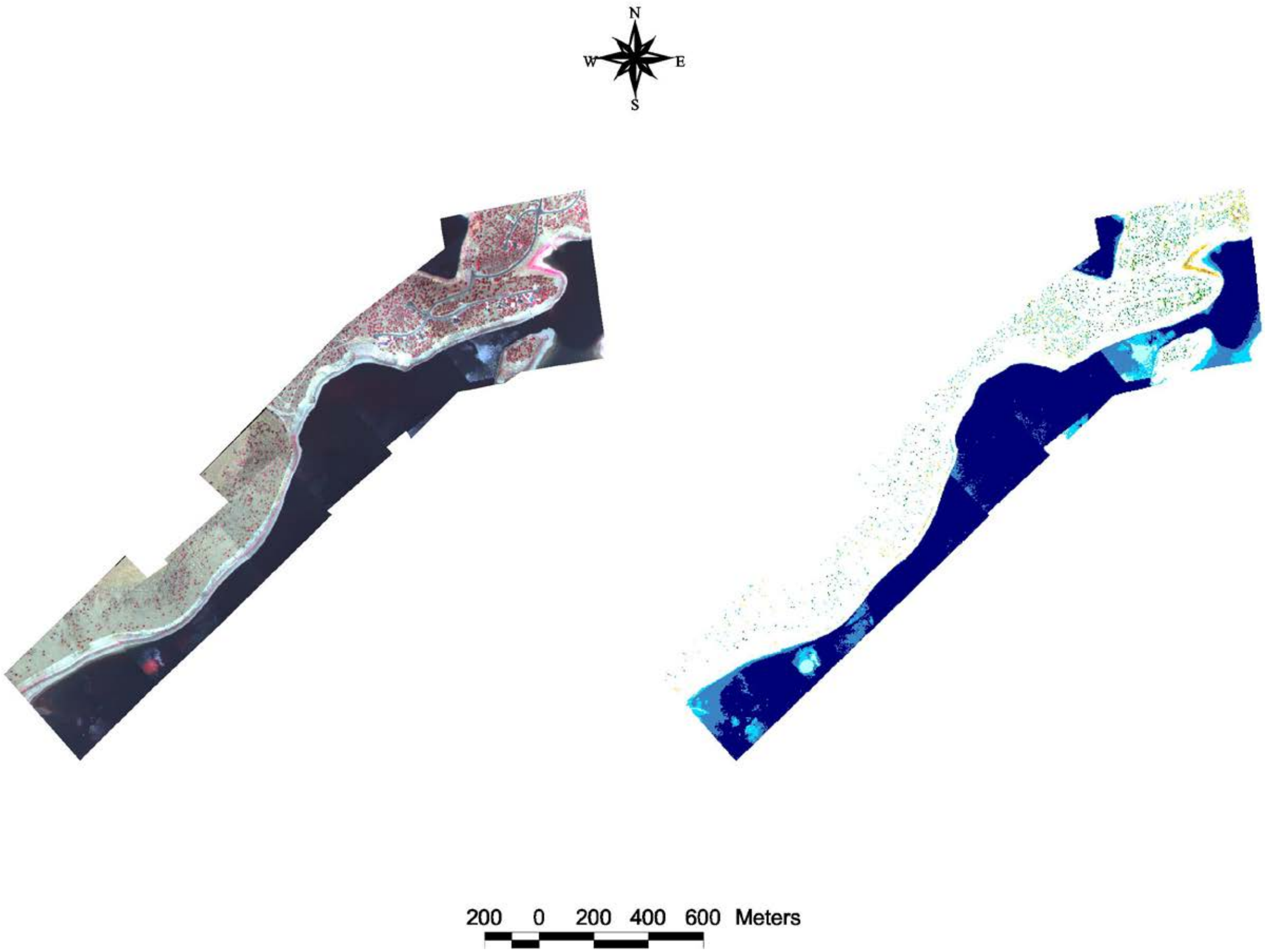

Figure A30. Shas1i-upper orthophoto (left) and classified image (right)

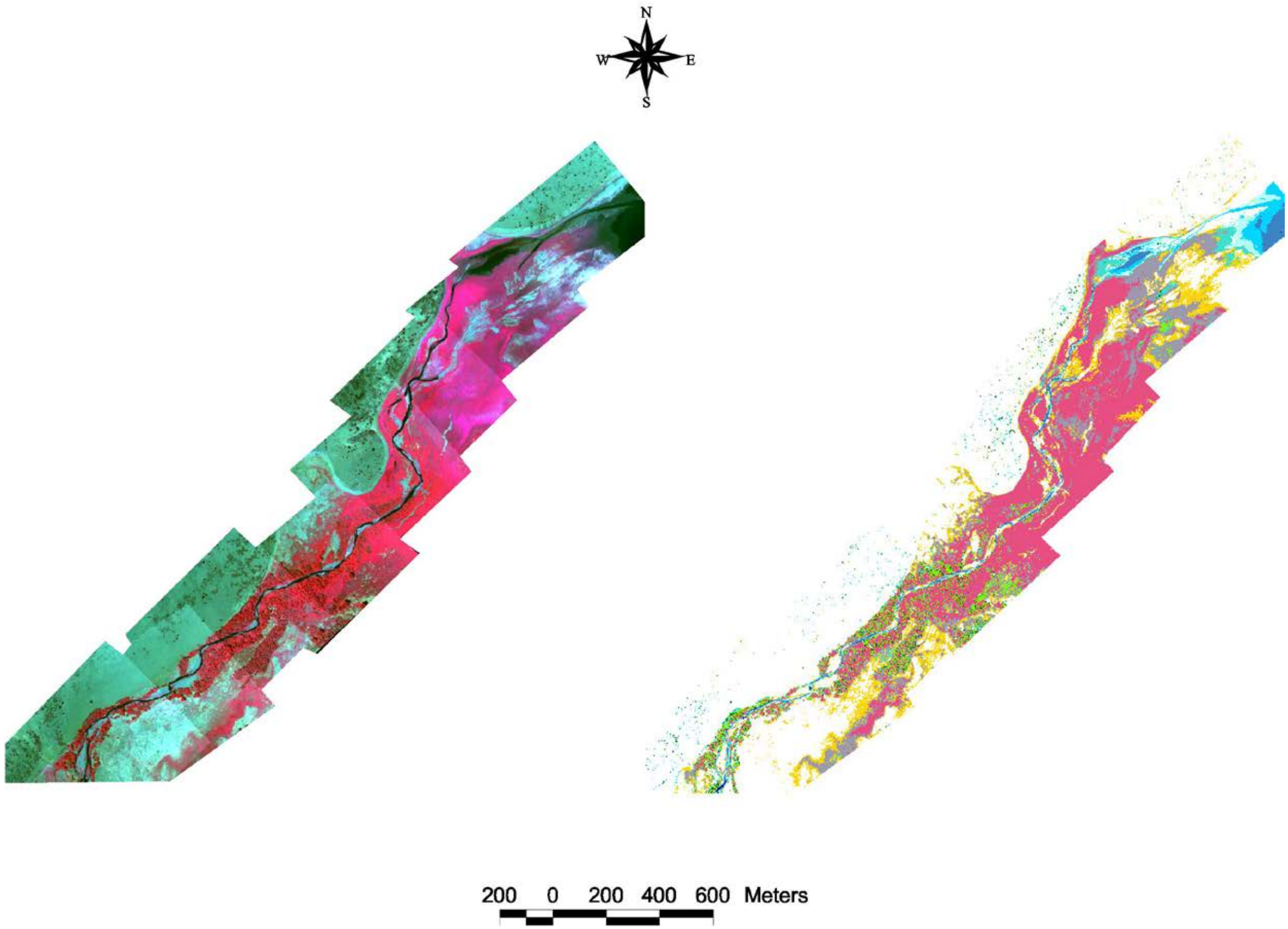

Figure A31. Shas1i-lower orthophoto (left) and classified image (right)

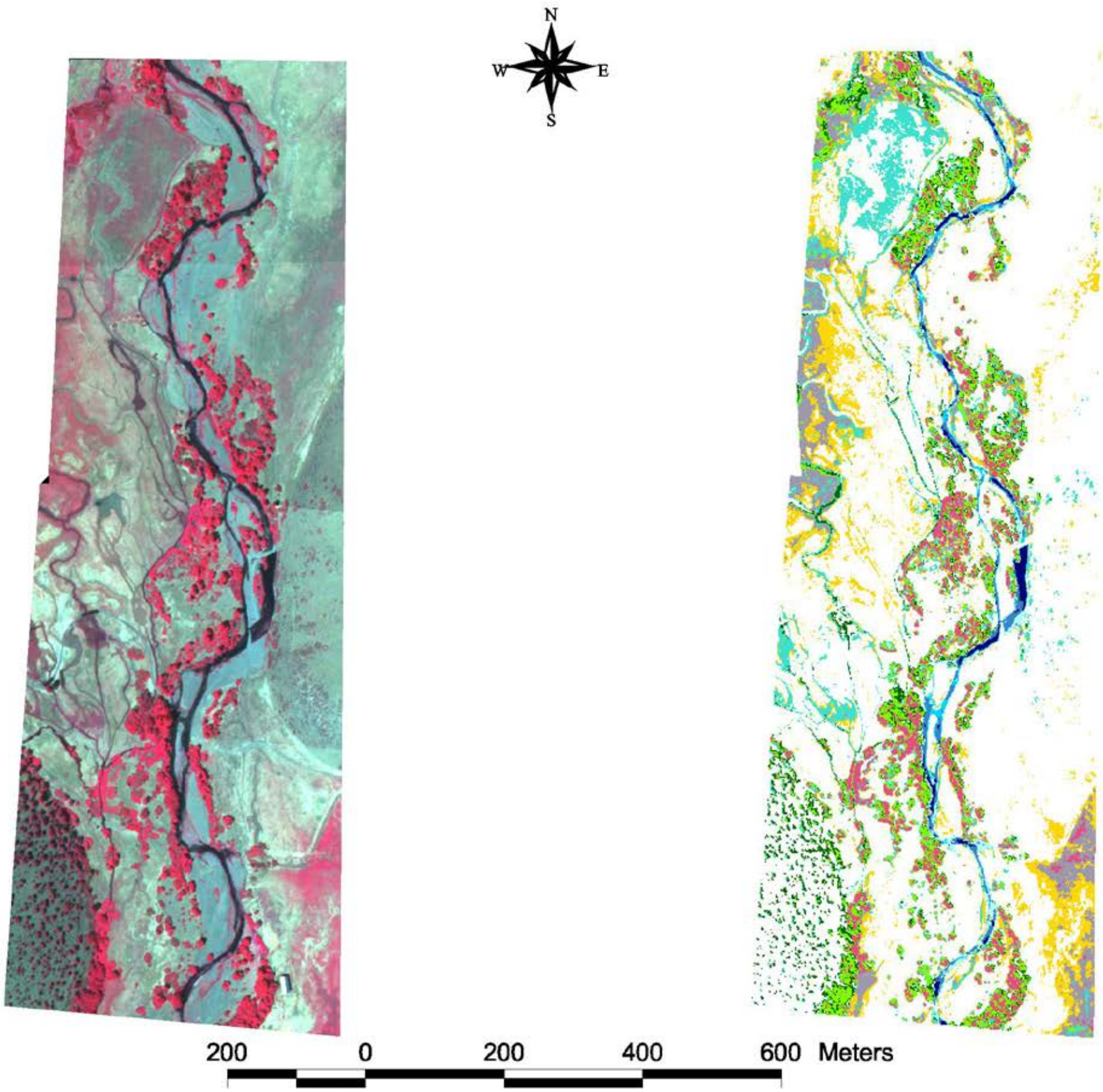

Figure A32. Shas1j orthophoto (left) and classified image (right)

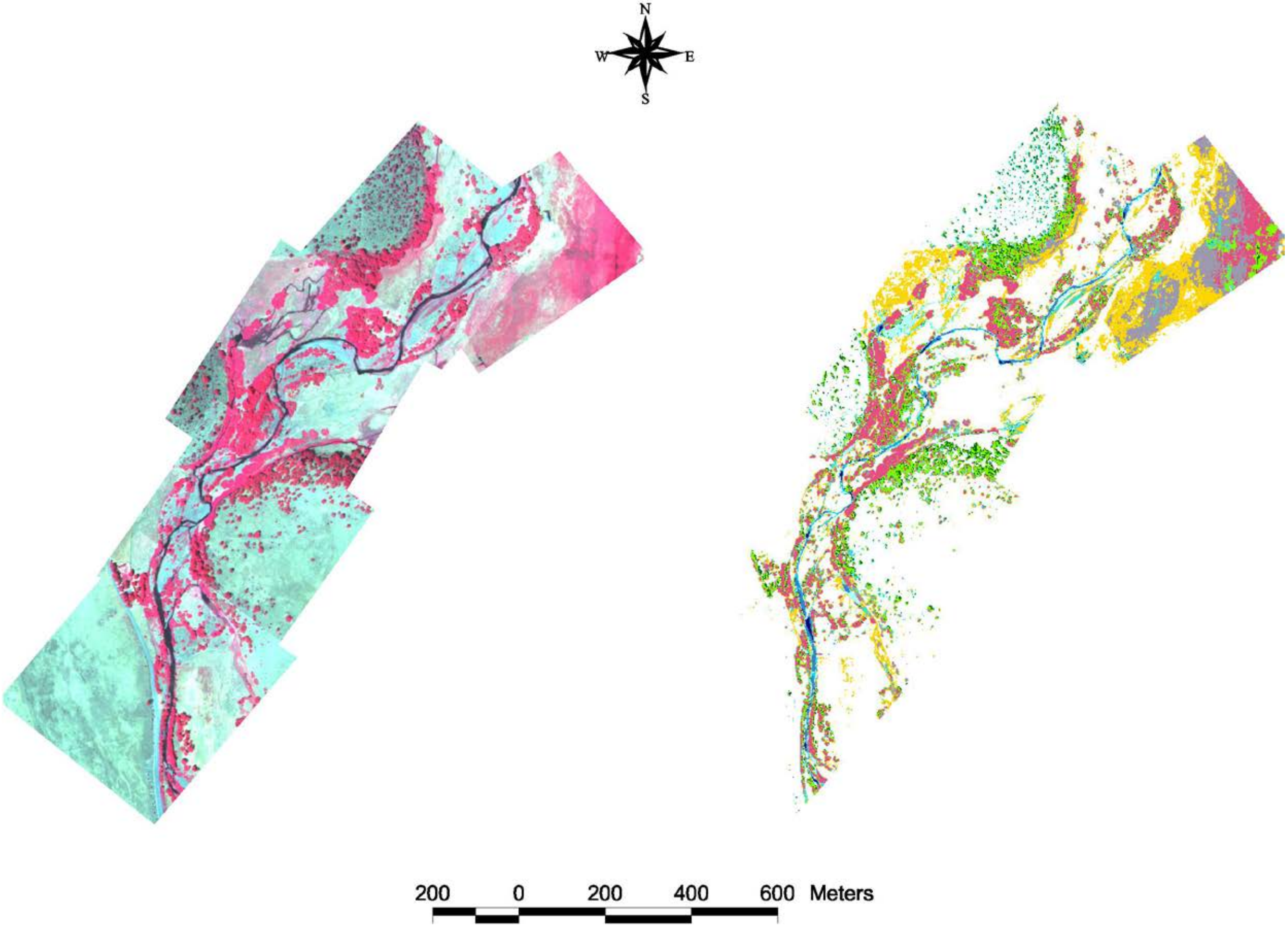

Figure A33. Shas1k orthophoto (left) and classified image (right)

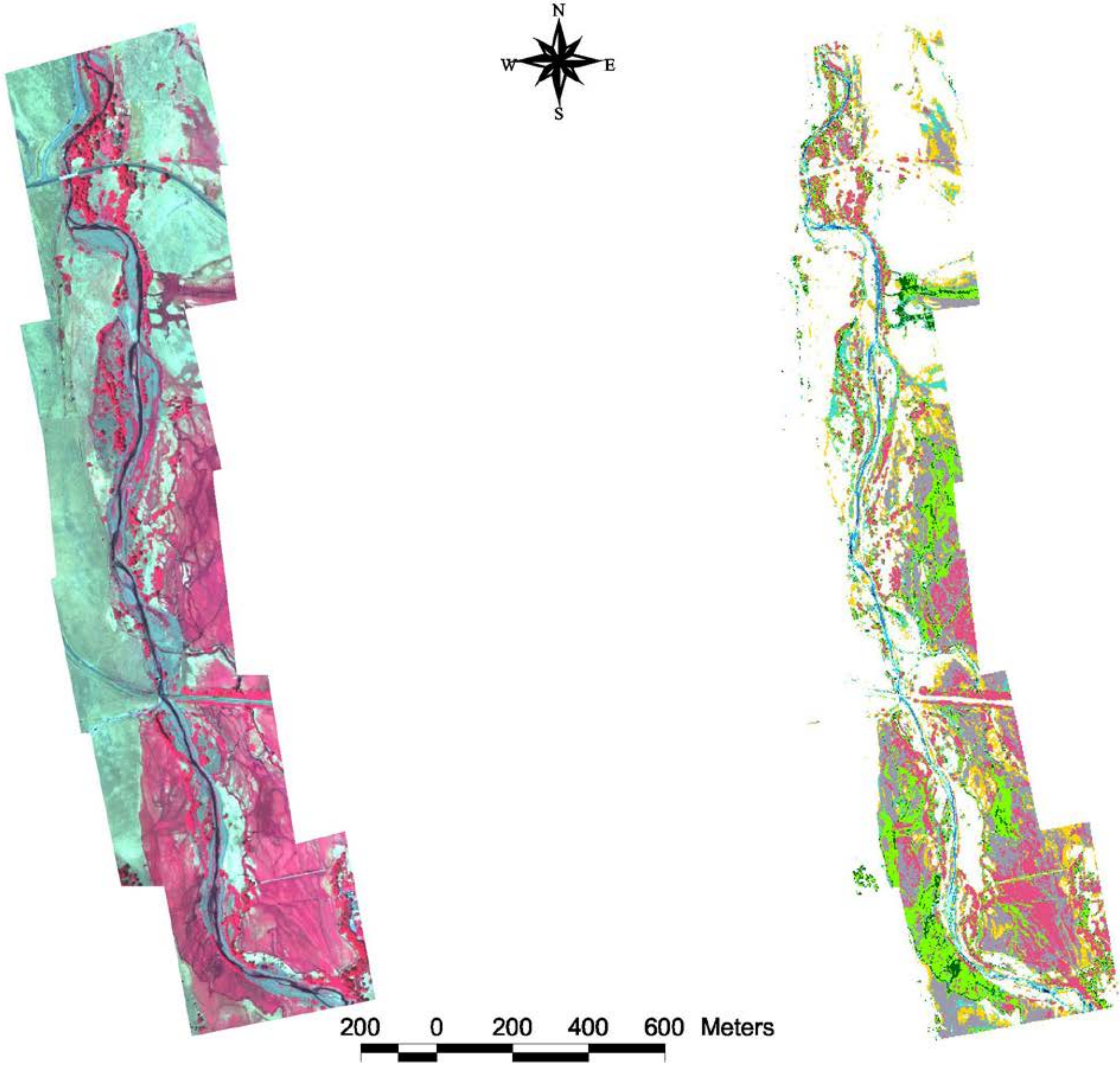

Figure A34. Shas1l orthophoto (left) and classified image (right)

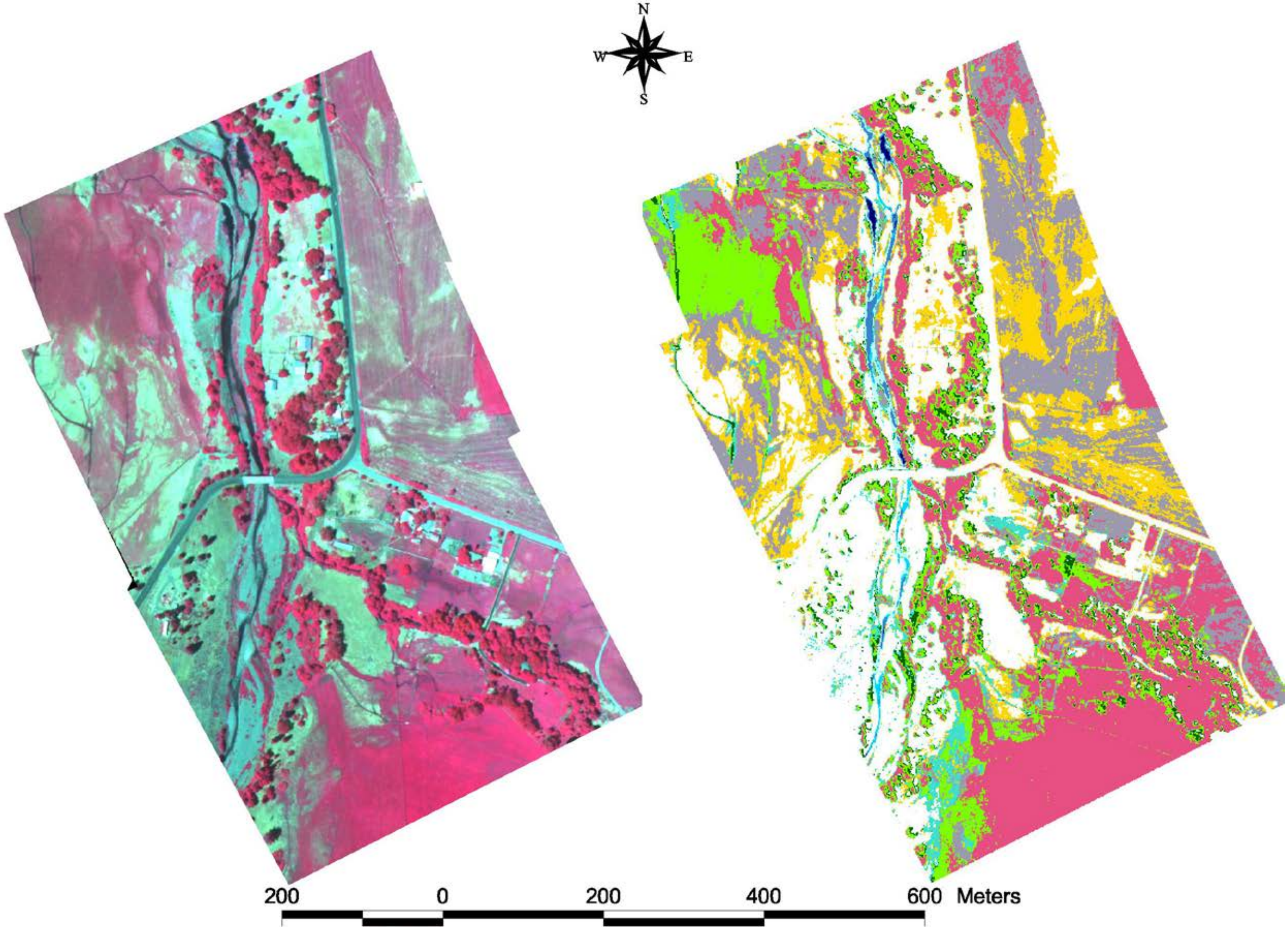

Figure A35. Shas1m orthophoto (left) and classified image (right)

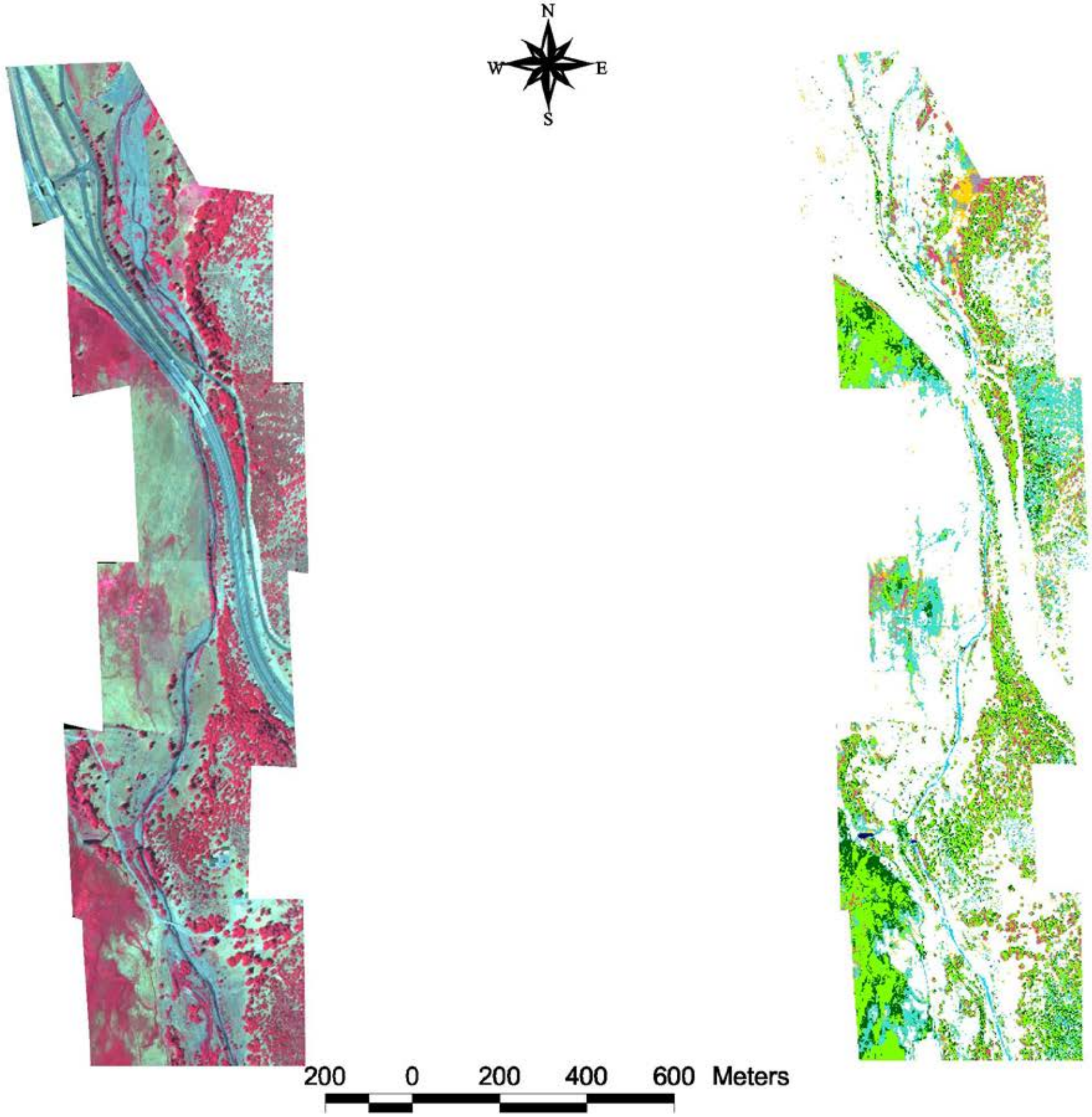

Figure A36. Shas1n orthophoto (left) and classified image (right)

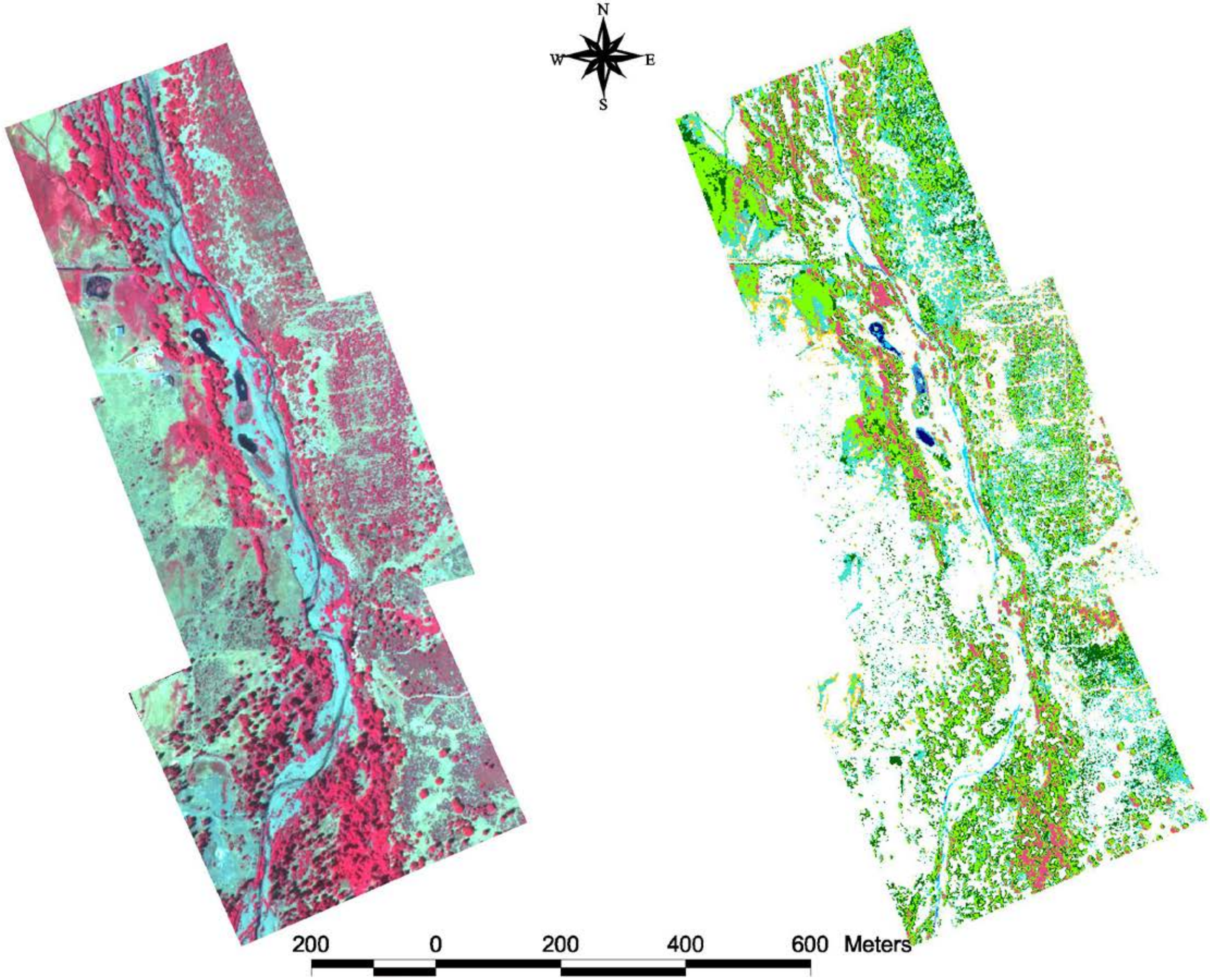

Figure A37. Shas1o orthophoto (left) and classified image (right)

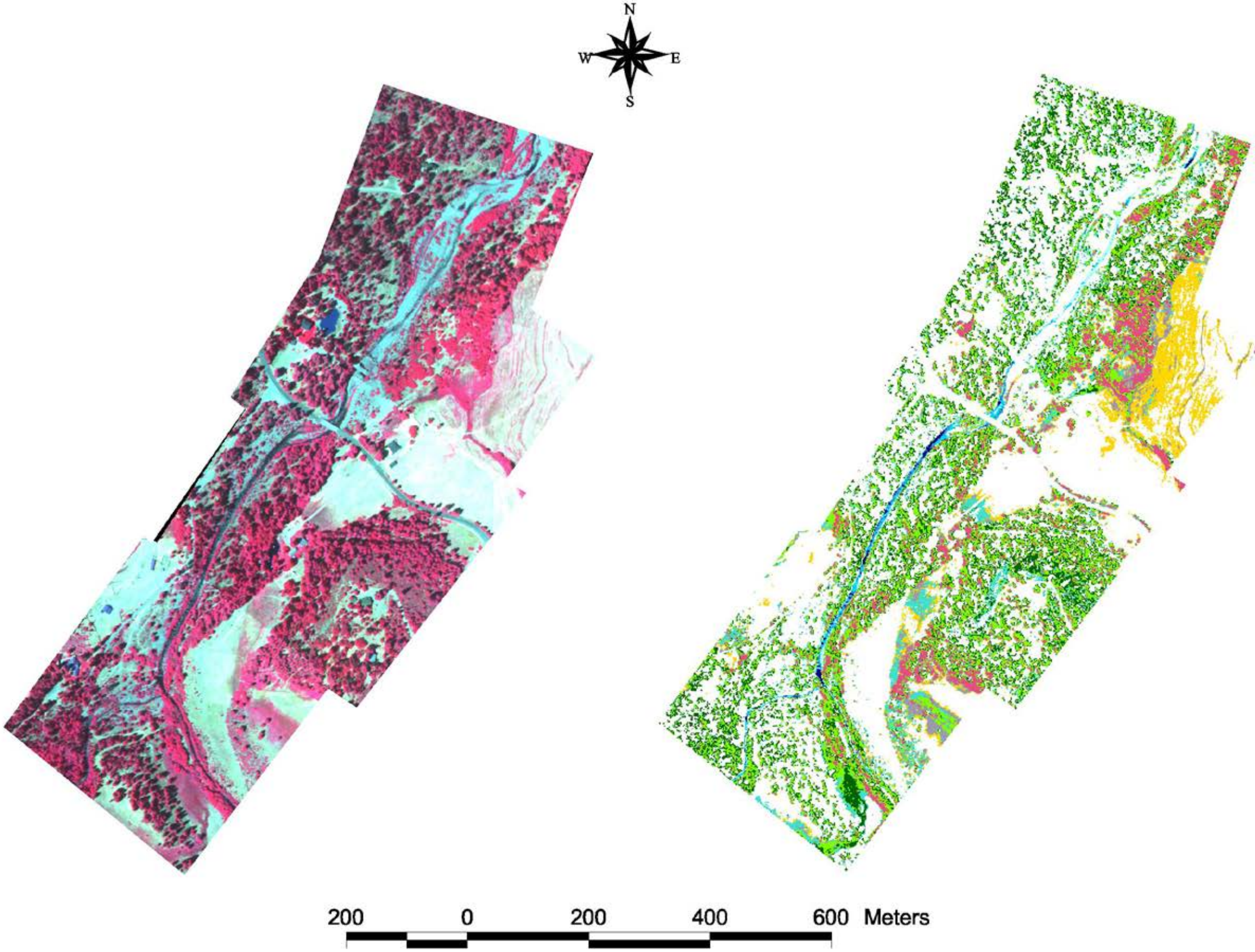

Figure A38. Shas1p orthophoto (left) and classified image (right)

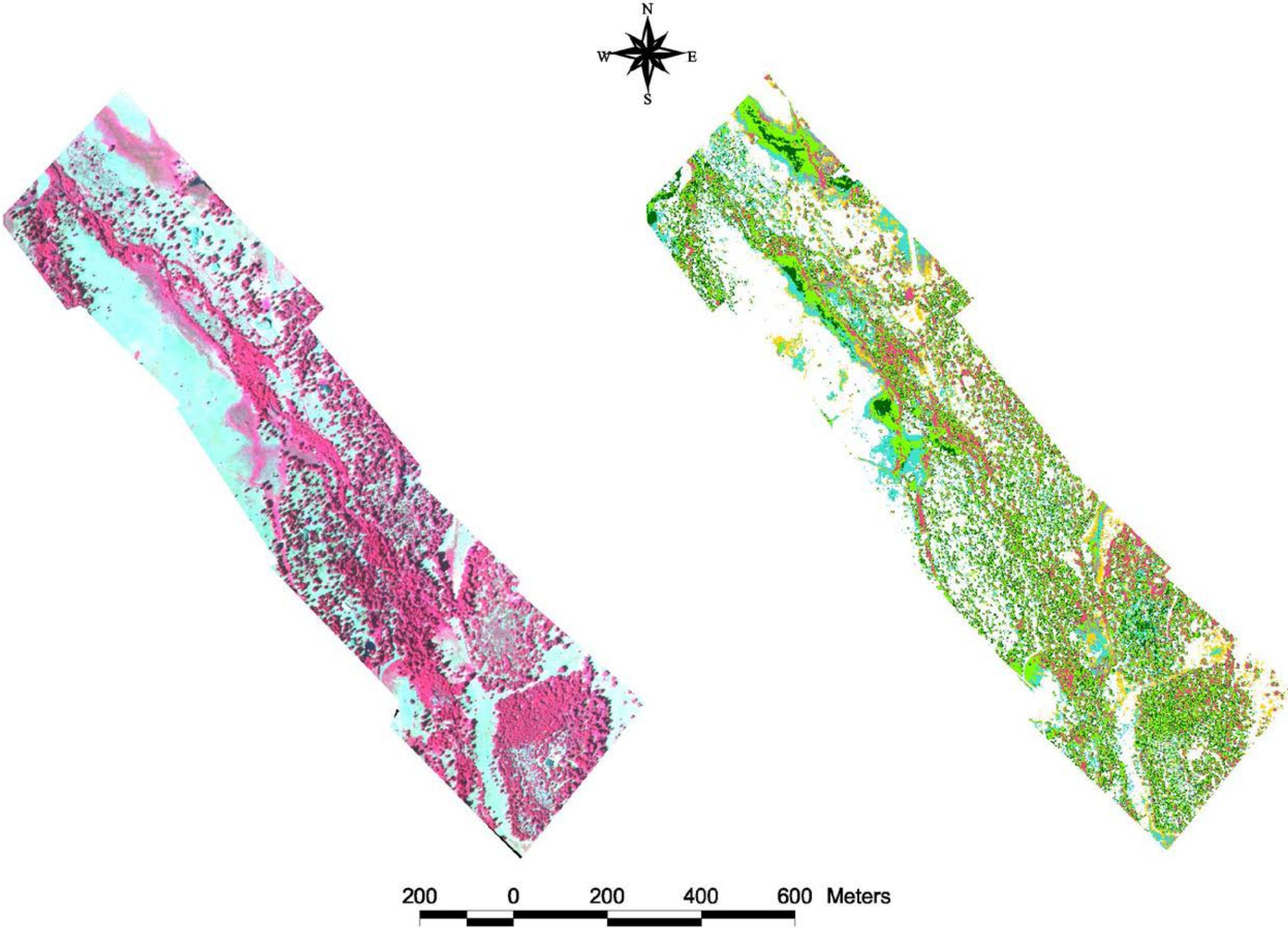

Figure A39. Shas1q orthophoto (left) and classified image (right)

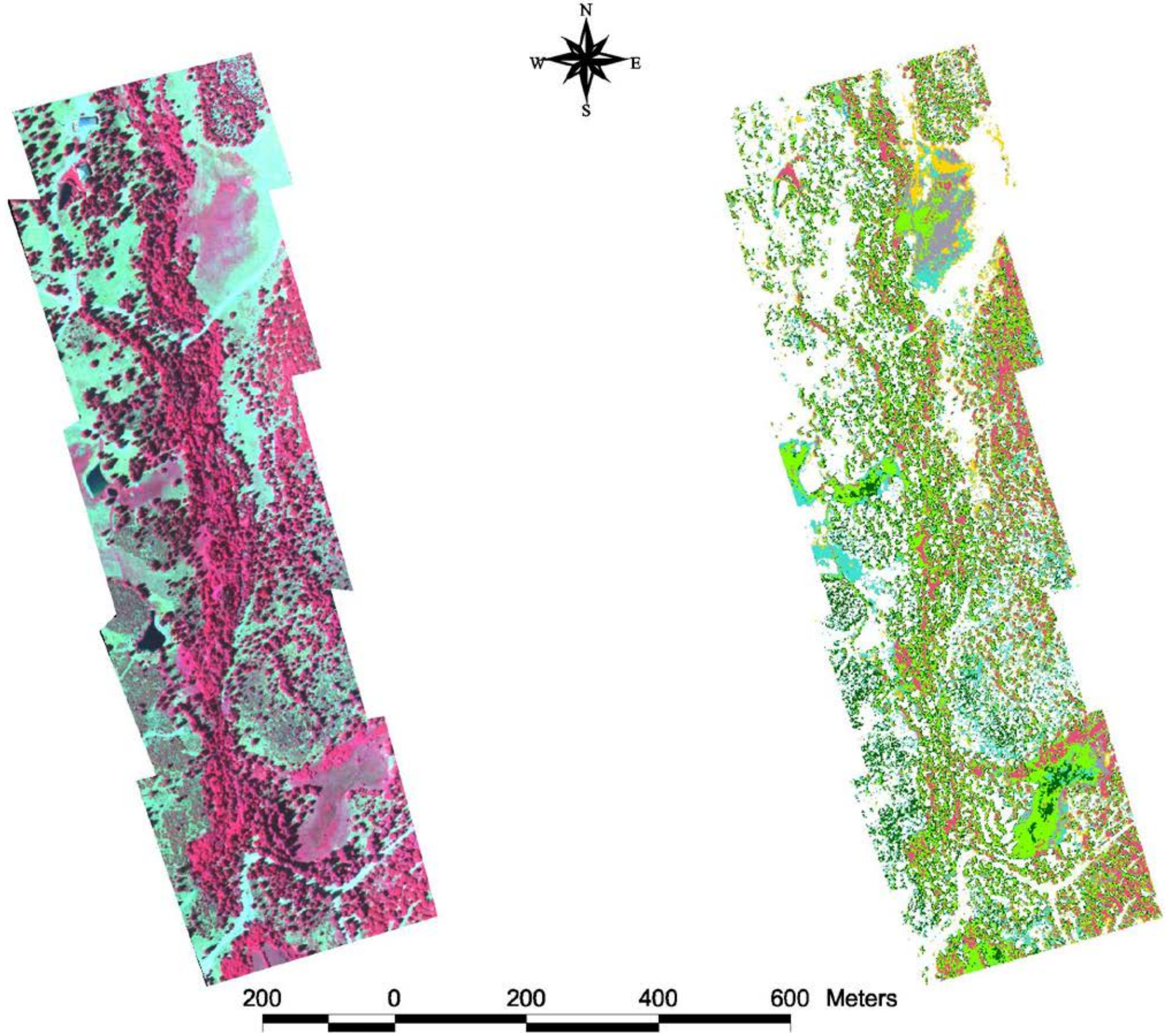

Figure A40. Shas1r orthophoto (left) and classified image (right)

Appendix B

```
Identification_Information:
  Citation:
    Citation_Information:
      Originator: Institute for Natural Systems Engineering / Utah
Water Research Lab / Utah State University
      Publication_Date: 20060410
      Title: Shasta River False Color Orthophoto Imagery
      Geospatial_Data_Presentation_Form: remote-sensing image
      Other_Citation_Details: Riparian Community and Aquatic Habitat
Classification for the Shasta River
      Online_Linkage: \\Steelhead\F\Shasta\Orthophotos\Shas0\ar000-
ar006\shas0a-ortho-wtr-str.img
  Description:
    Abstract:
      This dataset is a collection of false color orthophotos covering
the Shasta River

      An orthophoto is remotely sensed image data in which displacement
of features in the image caused by terrain relief and sensor
orientation have been mathematically removed. Orthophotography combines
the image characteristics of a photograph with the geometric qualities
of a map.

      Imagery was acquired on 20020727. Based on the desired nominal
0.5 m resolution and terrain relief (which constrains flight
parameters), aircraft altitude, lens used, and 1/f were determined.
This gave a footprint for each image of approximately 1 square
kilometer (2044 x 2029 pixels).
      The projected coordinate system is UTM zone 10 N, NAD 83, GRS 80,
Units Meters.
    Purpose: The goal of this project is to update the Shasta River
with Orthophoto imagery and Classified imagery representing Riparian
Communities and Aquatic Habitats
    Supplemental_Information:
      The Utah State University (USU) airborne multispectral digital
system (Neale, 1991; Neale and Crowther, 1994) utilizes three Kodak
Megaplus 4.2i digital frame cameras with CCD sensors containing 2044 x
2029 pixels.  Interference filters placed over the 20 mm Nikon lenses
form spectral bands centered in the green (0.55  m), red (0.67  m) and
near-infrared (0.80  m) portions of the electromagnetic spectrum.  An
Exotech four-band radiometer with Landsat Thematic Mapper bands TM1-4,
with wavelengths similar to the digital camera spectral bands is used
for the absolute calibration of the system in terms of radiance.  The
instruments are mounted on micrometer adjustable mounts so that the
three cameras can be aligned to view the same area.  Usually, the
cameras are aligned to infinity and the registration of the imagery is
done during post processing using procedures and automated routines
developed in-house.  The current USU system uses three EPIX frame
grabbing and digital control boards in a special rack-mounted Pentium
PC computer.  The boards control the digital cameras through specially
designed software, calculating the frequency of image acquisition
according to altitude, speed and desired overlap between images.  The
software also allows for setting the camera shutter speed and
automatically names and stores the files as they are acquired, using a
```

selected project prefix. GPS-based coordinated universal time is used to co-locate the center of each image with GPS positions acquired at one-second intervals.

The system is mounted in a Piper Seneca II, through a hole in the belly of the aircraft in the rear baggage compartment. The three Kodak digital cameras are mounted inside a carbon graphite composite cylinder, which allows compensation of aircraft yaw angle. An equipment rack holds the computer, monitors, GPS encoders, S-VHS recorder, and thermal-IR scanner controller box. An INFRAMETRICS 760 thermal IR camera is also integrated for acquiring concurrent thermal infrared imagery and is mounted in front of the cylinder through its own porthole. The output of this camera is recorded on a S-VHS recorder for later digitization and processing. A color camera mounted through a third porthole provides color video footage with encoded GPS coordinates for a quick review of the area covered with the digital system. A second video camera is mounted in the nose of the aircraft at 60 and aids in the visual navigation of the aircraft when filming river systems.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20020727
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -122.601251
East_Bounding_Coordinate: -122.586516
North_Bounding_Coordinate: 41.834332
South_Bounding_Coordinate: 41.814839
Keywords:
Theme:
Theme_Keyword: Orthophoto
Theme_Keyword: 3-Band
Theme_Keyword: Infrared
Theme:
Theme_Keyword_Thesaurus: none
Theme_Keyword: Riparian Community
Theme_Keyword: Aquatic Habitat
Place:
Place_Keyword: Shasta River
Place_Keyword: Siskiyou County
Place_Keyword: California
Place_Keyword: U.S.A
Place:
Place_Keyword_Thesaurus: none
Access_Constraints: This data is provided to Shasta and shall be governed by their access constraint policy
Use_Constraints: This data is provided to Shasta and shall be governed by their use constraint policy
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Thom Hardy

```
        Contact_Organization: Utah Water Research Lab / Utah State
University
      Contact_Position: Assistant Director
      Contact_Address:
        Address_Type: mailing address
        Address: 8200 Old Main Hill
        City: Logan
        State_or_Province: Utah
        Postal_Code: 84322
        Country: U.S.A
      Contact_Address:
        Address_Type: physical address
      Contact_Voice_Telephone: (435) 797-2824
      Contact_Facsimile_Telephone: (435) 797-8038
      Contact_Electronic_Mail_Address: hardy@cc.usu.edu
      Hours_of_Service: 9:00 am - 5:00 pm
  Data_Set_Credit: Institute for Natural Systems Engineering / Utah
Water Research Lab / Utah State University
  Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build
2600) Service Pack 2; ESRI ArcCatalog 9.0.0.535
Data_Quality_Information:
  Positional_Accuracy:
    Horizontal_Positional_Accuracy:
      Horizontal_Positional_Accuracy_Report:
        The horizontal accuracy of the orthophoto imagery is expressed
as an estimated root mean square error (RMSE)
        The horizontal accuracy of the images varied by flightline.
        The RMSE value varied between 0.5 and 1.0 for all imagery.
  Lineage:
    Process_Step:
      Process_Description:
        Processing of the raw imagery to allow classification and
analysis consists of numerous steps.
        1) Geometric correction - Lens imperfections cause geometric
distortions that increase at the edges of the image scene.
        2) Vignetting/Sensor sensitivity - Vignetting and variation in
the sensitivity of the sensor chip result in non-uniform readings for
uniform input radiation.
        3) Rectification - The individual spectral bands are registered
to the same image coordinate system to allow construction of the 3band
composite image file.
        4) Radiometric - Normalization of each scene to correct for
differences in uniform solar irradiance due to time difference, haze,
etc.
      Process_Date: 20060103
      Process_Contact:
        Contact_Information:
          Contact_Organization_Primary:
            Contact_Organization: Institute for Natural Systems
Engineering / Utah Water Research Lab / Utah State University
            Contact_Person: Shannon Clemens
          Contact_Position: Research Assistant
          Contact_Address:
            Address_Type: mailing address
            Address: 8200 Old Main Hill
            City: Logan
            State_or_Province: Utah
```

```
          Postal_Code: 84322
          Country: U.S.A
        Contact_Voice_Telephone: (435) 797-1184
        Contact_Facsimile_Telephone: (435) 797-8038
        Contact_Electronic_Mail_Address: srclemens@usu.cc.edu
        Hours_of_Service: 9:00 am - 5:00 pm MST
Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Raster
  Raster_Object_Information:
    Raster_Object_Type: Pixel
    Row_Count: 4317
    Column_Count: 2427
    Vertical_Count: 1
Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Grid_Coordinate_System:
        Grid_Coordinate_System_Name: Universal Transverse Mercator
        Universal_Transverse_Mercator:
          UTM_Zone_Number: 10
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -123.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: row and column
        Coordinate_Representation:
          Abscissa_Resolution: 0.500000
          Ordinate_Resolution: 0.500000
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
Distribution_Information:
  Distributor:
    Contact_Information:
      Contact_Organization_Primary:
        Contact_Organization: Utah Water Research Lab / Utah State
University
        Contact_Person: Thom Hardy
      Contact_Position: Assistant Director
      Contact_Address:
        Address_Type: mailing address
        Address: INSE
        Address: Utah Water Research Lab
        Address: 8200 Old Main Hill
        City: Logan
        State_or_Province: UT
        Postal_Code: 84322
        Country: U.S.A
      Contact_Voice_Telephone: (435) 797-2824
      Contact_Electronic_Mail_Address: hardy@cc.usu.edu
      Hours_of_Service: 9:00 am - 5:00 pm
```

Resource_Description: Downloadable Data
Distribution_Liability: Utah State University shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics (i.e. "GIF or JPG" format files) are not legal documents and are not intended to be used as such. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data. Utah State University gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. Although these data have been processed successfully on computer systems at Utah State University, no warranty expressed or implied is made regarding the utility of the data on other systems for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: ERDAS
File_Decompression_Technique: no compression applied
Transfer_Size: 0.000
Digital_Transfer_Option:
Offline_Option:
Offline_Media: CD-ROM
Recording_Format: CD-R
Fees: To be determined
Ordering_Instructions:
CD-ROM's with project and Imagery will be provided to U.S. Fish and Wildlife Service
who will then be responsible for distribution.
Technical_Prerequisites:
Provided to U.S. Fish and Wildlife Service
Coastal California Fish and Wildlife Office
Arcata FWO,
1655 Heindon Road
Arcata, CA 95521
Who will in turn become the distributor for this dataset.
Metadata_Reference_Information:
Metadata_Date: 20060407
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Utah Water Research Lab, Utah State University
Contact_Person: Mark Winkelaar
Contact_Position: GIS Specialist
Contact_Address:
Address_Type: mailing address
Address: 8200 Old Main Hill
City: Logan
State_or_Province: UT
Postal_Code: 84322
Country: USA
Contact_Address:

```
        Address_Type: physical address
        Address: 1600 Canyon Road
        City: Logan
        State_or_Province: UT
        Postal_Code: 84321
        Country: USA
      Contact_Voice_Telephone: (435) 797-1184
  Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial
Metadata
  Metadata_Standard_Version: FGDC-STD-001-1998
  Metadata_Time_Convention: local time
  Metadata_Extensions:
    Online_Linkage: http://www.esri.com/metadata/esriprof80.html
    Profile_Name: ESRI Metadata Profile
  Metadata_Extensions:
    Online_Linkage: http://www.esri.com/metadata/esriprof80.html
    Profile_Name: ESRI Metadata Profile
```