The Effects of Polynomial Interpolation and Resampling Methods in Geometric Correction on the Land-cover Classification Accuracy of Landsat-8 OLI Imagery: A Case Study of Kulon Progo Area, Yogyakarta

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ABSTRACT

Geometric correction is an important step in image pre-processing, because it determines the the positional accuracy of the data. However, the geometric correction also includes pixel values interpolation in their new position, so that it may change original values. This study objectives were (a) to provide information on the effect of geometric correction models on the accuracy of land-cover classification, especially using per-pixel classification with maximum likelihood algorithm; and (b) to assess the effect of image resampling methods on the accuracy of the multispectral classification results. This study made use of Landsat 8 OLI Level 1G imagery covering Kulon Progo Area, Yogyakarta, so that several ground control points (GCPs) were needed to suppress geometric errors. Non-systematic geometric correction was undertaken using first, second and third order polynomial transformations. After that, several resampling processes were applied to the geometrically corrected image, i.e. Nearest Neighbour, Bilinear and Cubic Convolution interpolations. It was found that the affine transformation using six GCPs distributed over the edges of the image, delivered an RMSE value of 0.355539. In addition, the second order polynomial with 10 GCPs scattered around the edges of the image gave an RMSE value of 0.178053. While the third order polynomial transformation with 17 GCPs that were evenly distributed in the image produced an RMSE value of 0.100343. The resampling process produced new images with new pixel values, which were then tested with respect to their classification accuracies based on maximum likelihood algorithm. Samples for accuracy assessment were taken using stratified random sampling strategy. Samples were taken in terms of polygons whose size was determined by considering the pixels' displacement as the results of geometric corrections. This study also found that resampling with nearest neighbour interpolation using third order polynomial equation produced the best overall accuracy of 75.46%, with a Kappa of 0.7032.

Keywords: Geometric correction, polynomial interpolation, resampling method, land-cover classification

1. INTRODUCTION

Remotely sensed imagery recorded by satellites contains many errors, particularly the ones provided as a raw data. These errors can be caused by atmospheric conditions, satellite sensors, recording angles, sun elevation and Earth surface configuration. The variability of the Earth's curvature and the topography cause geometric errors during satellite image recording. So that other geometric errors appear in the image, the difference in height of the object on the earth's surface is directly recorded so as to produce an image with a non-uniform scale [1].

Geometric correction is the process of correcting geometric errors due to image distortion to obtain a relationship between the image coordinate and the geographic coordinate systems, through data calibration of sensor, altitude, ground control points, atmospheric conditions and others [2]. Random geometric errors cannot be predicted, but the proportion of geometric errors can be predicted through data matrices or data tracking and analysis of ground control points. The magnitude of the error can be corrected using non-systematic methods. This transformation process requires the availability of topographic maps or ground control points that are accurate in accordance with image coverage.

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Coordinate transformation is a procedure for changing the coordinate system from one system to another [3]. The coordinate transformation model is used for random geometric corrections, which assume that the ground control points are evenly distributed on the image, so that coordinate transformations can be expressed with polynomials. Some transformation models that use the basis of polynomials include affine, pseudo affine and projective transformation [4].

The resampling process is a transformation process from the raster input value (input image) to the raster output value (output image) [5]. The example of resampling is rectifying and registering the output image, because of the pixels in the original image rarely resemble reference images, so the original pixels are changed so that new data values in the output image can be calculated. In digital image processing known three methods of image resampling, i.e. nearest neighbor, bilinear interpolation, and cubic convolution.

There are two methods for producing land cover information, i.e. visual interpretation and digital classification. Pixel-based digital classification is used to extract digital values of images to produce land cover maps. The multispectral classification of the maximum likelihood algorithm uses the basis of probability calculations, and the probability for all classes can be treated with the same probability to be presented in the image [1].

This geometry correction refers to a particular point on the imagery to the same point on the ground or on the map, so that indirectly the uncorrected imagery is forced to occupy the space that was created before. It should be noted that the shift in the pixel values in the original image will include changes in the spectral value information as well. Whereas the change in pixel value will affect the results of the multispectral classification because this classification is based on the pixel value of each object that appears on the multispectral image. Moreover, each resampling algorithm will produce a different new output value. Where the Maximum Likelihood multispectral classification algorithm considers image statistics, as well as using the basis for calculating image pixel probabilities in the classification process. So the study objectives were (a) to provide information on the effect of geometric correction models on the accuracy of land-cover classification, especially using per-pixel classification with maximum likelihood algorithm; and (b) to assess the effect of image resampling methods on the accuracy of the multispectral classification results.

2. METHODS

2.1 Research Location

The study area is located around Menoreh Hills, which is part of Kulon Progo Regency. This location was selected as the study area due to its topographic characteristics, ranging from gentle slopes to hilly and even mountainous. It was an ideal condition to be used as a basis for such research, in which the geometric correction process considers the differences in topography. In addition, in the study area, there were variations in land cover types, particularly in the form of high to low density vegetation, built up areas, and water bodies.

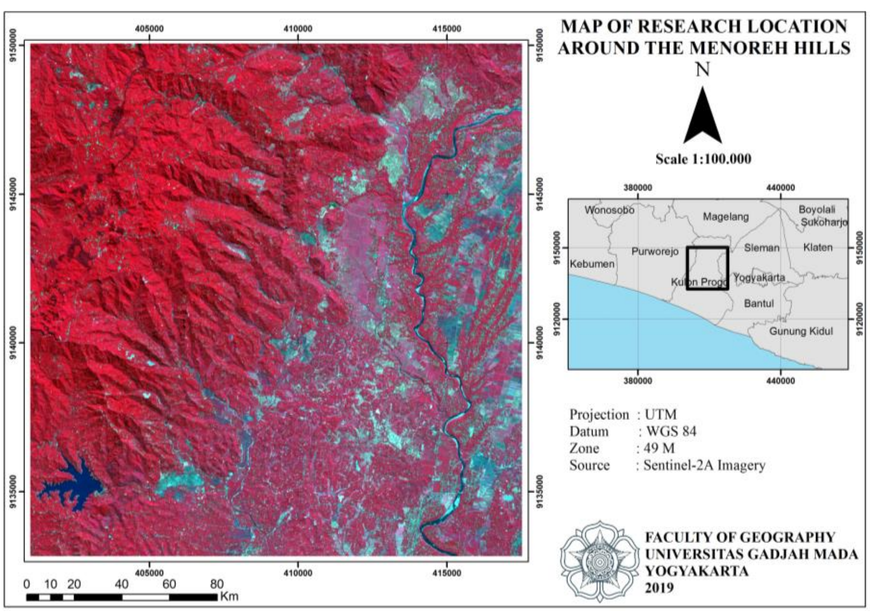


Figure 1. Research location

2.2 Data processing stage

2.2.1 Processing of Sentinel-2A imagery

Land-cover classification through visual interpretation is done by limiting land cover polygons manually to digital image data. Delineation is carried out on Sentinel-2A imagery that has been geometrically corrected systematically and non-systematically. The delineation process is carried out using the reference level 2 Spectral Dimensional Multipurpose Land-Cover Classification Scheme [6] with a scale of mapping 1: 25,000 which can be seen in Table 1.

2.2.2 Geometric correction of Landsat 8 L1G images

Ground control points (GCP) were taken using reference images, that is Sentinel-2A images. Sentinel-2A imagery has a 10 m of spatial resolution on visible-NIR spectrum. The use of the VNIR spectrum due to the need for imagery analysis is limited to the visual interpretation of land-covers only. The results of the visual interpretation are used as a reference map for accuracy testing in the multispectral classification of Landsat 8 Imagery, so the pixel accuracy test for polygons will be better if the land cover polygon more detailed. Polygon-based accuracy testing for validation of extensive land cover maps is often seen as a cost-effective means of associating some level of confidence with land cover products [7]. On the other hand, the spatial resolution of sentinel images is three times more detailed than Landsat 8 imagery, so that at least one pixel value Sentinel-2A is one-third pixel of Landsat 8. If there is an error in accuracy, the accuracy is less than 0.5 pixels Landsat 8 image, then the value is still allowed to test image accuracy with a resolution of 30 m (Landsat Image) [8]. The pattern of distribution of ground control points basically produces the same imagery geometrically. However, the distribution needs to be considered because it is related to the final results which consider geometric accuracy and semantic accuracy of the map. In this study three models of GCP'S distribution patterns were used, i.e.: (a) pattern of control points on the edges of the image; (b) poving control point pattern (c) the pattern of control points is spread evenly. At least the magnitude of the RMSE value that can be received is 0.5 pixels. The RMSE and STD formulas are as follows [9]:

$$RMSE = \frac{\sqrt{(x' - x_{origin})^2 + (y' - y_{origin})^2}}{n}$$

$$\sigma_{x,y} = \frac{\sqrt{\sum_{i=1}^{n}((x_{origin} - x')^2 + (y_{origin} - y')^2)}}{n - u}$$

x', y' : the image coordinate resulting from geometric correction
$(x, y)_{origin}$: represents GCP coordinates in the reference field
n : the number of GCP'S

2.2.3 Image resampling

The image resampling process is a step that aims to change the pixel value of the image after making geometric correction. Image resampling method used is nearest neighbor, bilinear interpolation, and cubic convolution. The results of image resampling were assessed by visual quality and geometric distortion caused during the image resampling process.

2.2.4 Multispectral Classification Maximum likelihood

The multispectral classification used in this study was the supervised classification using maximum likelihood algorithm that considers the probability of pixel values to be assigned to particular class or category. The land cover classification scheme uses the Spectral Dimensional Multipurpose Land-Cover Classification Scheme Level 2 at 30 meters resolution that presented in Table 1.

Tabel 1. Spectral Dimension Multipurpose Land Cover Classification Scheme

Level 1	Level 2
C1 Water body	C11 Deep water
	C14 Turbid water
C2 Vegetation cover	C21_1 Woody broadleaves 1
	C21_2 Woody broadleaves 2
	C22_1 Non-woody broadleaves

	1
	C22_2 Non-woody broadleaves 2
	C22_3 Non-woody broadleaves 3
	C23 Needle leaves
C3 Soil/Open land	C31 Dry soil
	C32 Moist soil
	C33 Moist and wet surface
C4 Surface hardened and waterproof	C41 Asphalt and cemented surface
	C42 Hardened clay surface
	C44 Asbestos surface and zinc
Cloud	
Shadow	

Reference : Danoedoro, 2004;71-90

2.2.5 Sampling

This study uses stratified random sampling because it considers land cover classes in the image and in the field, and the affordability of objects in the field. In the accuracy test, the position of the object in the image with the position of the object in the field must have the same coordinates. Authors as mentioned in [10] suggested an equation that can be used as a reference in determining the minimum sample area, that is:

$$A = P(1+2L)$$

note :

A = minimum sample size in the field

P = image pixel size

L = approximate location accuracy, in pixel size (0-1)

2.2.6 Accuracy Test

A common method used to assess errors is the Error Matrix or often known as the Confusion Matrix [11]. Overall accuracy can be generated from the comparison of the correct number of pixels to the total number of pixels in the image. If the results of classification of remote sensing data show an accuracy of 85%, the data information is acceptable. Assessment of accuracy tests also uses the kappa coefficient [10]. Formulate the Kappa coefficient as follows [13]:

$$K = \frac{N\sum_{i=1}^{r} xii - \sum_{i-1}^{r}(X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{+i})}$$

note :

K : Kappa's Coefficient

N : the number of observation total

r : the number of row in error matrix

x_{ii} : the observations number of row i column i

x_{i+} : observations total on row i

x_{+i} : observations total on column i

3. RESULTS AND DISCUSSION

3.1 Visual Interpretation of Land-Cover

The land-cover classification is based on the level 2 multipurpose classification scheme of Danoedoro's [6] which has been modified on a scale of 1: 10.000 to 1: 30.000. The land-cover class produced from the results of visual interpretation amounted to 14 classes, that is: Deep water (C11), turbid water (C14), woody broadleaves 1 (C21), woody broadeaves 2 (C21), non-woody broadeaves 1 (C22_1), non-woody broadeaves 2 (C22_2), non-woody broadeaves 3 (C22_3), needle leaves (C23), dry soil (C31), moist soil (C32), moist and wet surface (C33), Asphalt and cemented surface (C41), hardened clay surface (C42), asbestos surface and zinc (C44). The results of the land cover classification using visual interpretation methods produced 1394 land cover polygons divided into 14 classes (figure 3). Sampling for land cover accuracy test is based on the Slovin formula [14], which is formulated as follows:.

$$n = \frac{N}{1 + Ne^2}$$

note :

n : number of sampel

N : number of population

e : desired level of significance

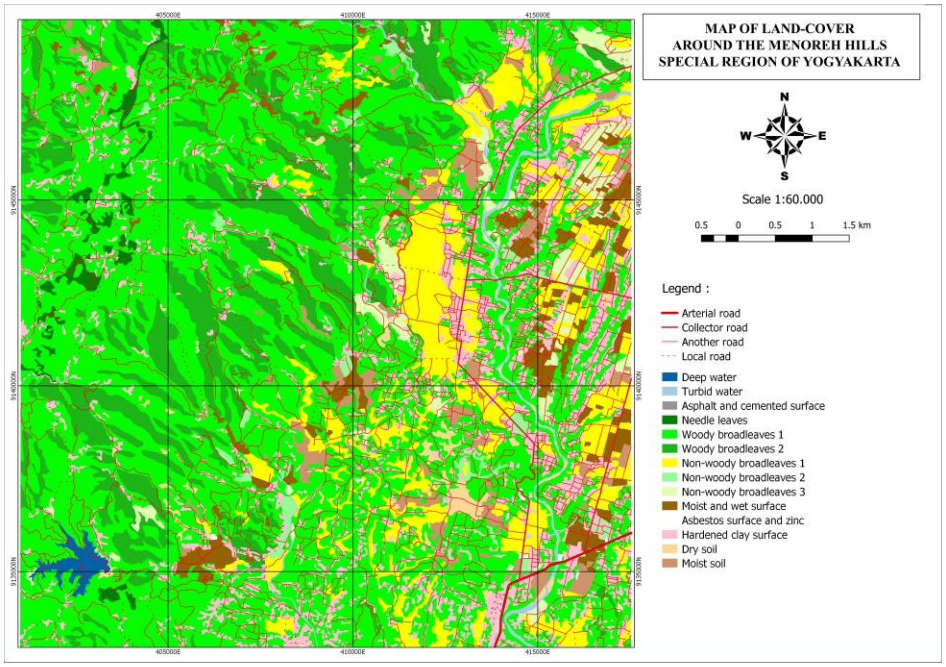


Figure 3. Land-cover map of visual interpetation result of Sentinel-2A Imagery

Population number or land cover polygon is 1394, so based on the Slovin formula obtained 263 minimum samples with a significance level of 0.55 (94.5%). The results of the field data accuracy test produce land-cover maps with an overall accuracy of 90% with a kappa index value of 0.85. Table 2 shows the producer's accuracy and user's accuracy of land cover results from visual interpretation.

Table 2 producer's accuracy and user's accuracy

Land-cover	Producer's Accuracy		User's Accuracy	
	Accuracy (%)	Ommission errors (%)	Accuracy (%)	Commission errors (%)
C11	100	0	100	0
C14	100	0	100	0
C41	100	0	100	0
C23	67	33	100	0
C21_1	97	2	100	0
C21_2	100	0	91	9
C22_1	73	26	73	26
C22_2	100	0	43	57
C22_3	100	0	100	0
C33	33	66	37,5	62,5

C44	50	50	100	0
C42	100	0	97	3
C31	33	66	25	75
C32	40	60	50	50

3.2. Geometric Correction

Geometric correction using polynomials requires some object to be used as tie points. The objects in the form of static appearance, such as roads, rivers, reservoirs, bridges, and permanent buildings. Geometric correction using affine method with 6 ground control points that were distributed on the edge of the image produced an RMSE of 0, 355539. Geometric correction with the second order polynomial method using 10 ground control point that were distributed around the image produces RMSE of 0.178053; whereas geometric correction with 3rd order polynomial method of field control points used amounted to 17 binding points which were evenly distributed in the image resulting in an RMSE of 0.100343. The RMSE value from geometric correction using the 3rd order polynomial was the best value as compared to the affine and 2nd order polynomial methods. The residual value of the image geometric correction is presented in Table 3.

Table 3. Residual value of geometric correction

	Affine	2nd order polynomial	3rd order polynomial
Number of tie point	6	10	17
RMSE	0,355539	0,178053	0,100343
Pixel displacement	10,66617 m	5,34159 m	3,01029 m

This study found that the factors influencing the RMSE values were the distribution of ground control points, number of ground control points, and order of polynomials. As viewed from those three factors, the level or order of polynomials was the most influential one. The more number of ground control points that used, followed by an increase of the order of polynomials, the better the RMSE value.

3.3. Resampling

The nearest neighbor, cubic convolution, and bilinear interpolation algorithms in geometric correction produced images with different pixel values. Generally speaking, visual differences can be seen in the results of resampling with the nearest neighbor algorithm, since the algorithm produces jagged images with broken appearance of pixels. On the other hand, the cubic convolution and bilinear interpolation algorithms produce finer and smoother image appearance. These differences can be seen in linear objects such as rivers, which can be seen in Figure 4.17.

The results of nearest neighbor resampling have fewer mixed pixels than those produced by other two algorithms. In image processing, the nearest neighbor algorithm also requires a fairly short time compared to bilinear interpolation and cubic convolution. The influencing factor is the number of pixels used as a reference, as already explained that bilinear interpolation uses the four closest neighbors, while the cubic convolution uses the 16 closest neighbors. But both algorithms produce finer output pixels. So that the two algorithm is good if used for visual analysis.

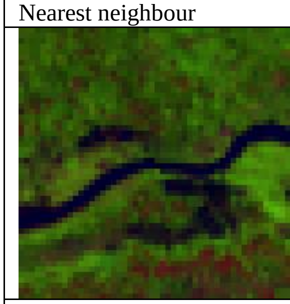
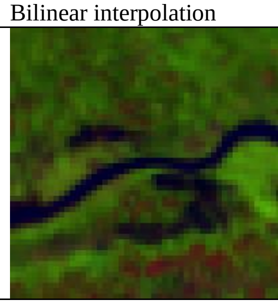
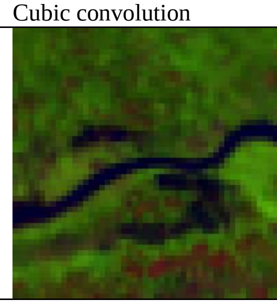
Nearest neighbour	Bilinear interpolation	Cubic convolution
		
Comparison of object appearance (river) between interpolation methods		

Figure 4. Comparison of the results of resampling the image resulting from geometric correction

3.4 Multispectral Classification Maximum likelihood

The use of the maximum likelihood algorithm is based on an algorithm that is considered statistically well established [1]. In addition, the difference in pixel values in each geometric and resampling correction result was also used as the basis for selecting the maximum likelihood algorithm, because this algorithm considers the pixels' probability values to be assigned to particular class. In conducting a multispectral classification it is necessary to consider several things such as image composite selection, and training areas or ROIs. Image composite that used was 654 (SWIR, NIR and Red), which was based on the clarity of the appearance of the image, which can distinguish various types of vegetation. The selection of image composites was also based on the statistical parameters used, *i.e.* Optimum Index Factor (OIF) developed by Chavez et al. [15]

Table 4 OIF calculation results for 6 channels

Rank	Band combination	OIF
1	4,5,6	3422,61
2	3,4,5	3352,14
3	3,5,6	3287,22
4	4,5,7	3254,02
5	3,5,7	3125,1
6	5,6,7	3050,96

Source: Processing on ILWIS software

Retrieval of ROI serves as a reference in creating land cover classes in the study area. The land cover class used is the same as the visual interpretation, which refers to the multipurpose classification of [6]. Differences in visual interpretation using Sentinel-2A imagery and multispectral classification based on 8 Landsat Imagery was that the later did not include the class of asphalt cover and cemented surface (C41). The choice of training area was based on the spectral characteristics of the object, *i.e.* hue and color. Furthermore, to assess the training area taking, statistical calculations were performed using the separability index. Evaluation of the level of separability of the sample were counducted using Transformed Divergence and distance of Jeffries-Matusita (JM). JM distances, which ranges between 0 and 2, provide a general measure of the separation between the two classes according to their possibilities [16].

The multispectral classification process with the maximum likelihood algorithm was implemented using ENVI 5.3 software. The results of the land cover classification with the maximum likelihood algorithm produced nine land cover maps. Each map was tested for accuracy on maps of visual interpretation and appearance of sentinel-2A images. Accuracy tests was carried out using a square-shaped polygon with an area taking into account the shift of pixel image to a map or reference image. Polygons to test the accuracy of each method are shown in Figure 5.

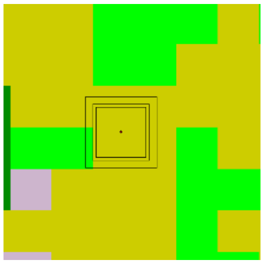


Figure 5. comparison of the area of the test polygon in the wide leaf cover class; not woody 1

The results of the multispectral classification were assessed using the configuration matrix and Kappa index tables presented in Tables 5 and Table 6. From these results it can be seen that the transformation using 3rd order polynomials produced the best accuracy value among other geometric correction methods. The 3rd order polynomial with the nearest neighbor resampling method produced the highest accuracy of 75.43% with a Kappa coefficient of 0.70298. Meanwhile, the transformation of 3rd polynomials with bilinear interpolation and cubic convolution resampling methods yielded the same values, *i.e*. 72.2359%.

From the calculation of overrall accuracies, the transformation of the 2nd order polynomial with the nearest neighbor algorithm produces a land cover map with the lowest accuracy value of 68.0590%. The affine transformation with bigger RMSE value, as compared to the 2nd order polynomial transformation, produced a fairly good accuracy on the three resampling algorithms. Therefore, this study found that the higher order polynomial transformation was not a guarantee to produce output images with better spectral quality (for multispectral classification) in comparison with the lower order polynomials.

Table 5. Overall accuracy of the results of the multispectral classification

Geometric correction	Resampling		
	Cubic convolution	Bilinear interpolation	Nearest neighbour
Affine	70,5160 %	70,2703 %	71,0074 %
2nd Order Polynomial	70,2703 %	71,7445 %	68,0590 %
3rd Order Polynomial	72,2359 %	72,2359 %	75,4300 %

Table 6. The kappa index coefficient results from the multispectral classification

Geometric correction	Resampling		
	Cubic convolution	Bilinear interpolation	Nearest neighbour
Affine	0,638157459	0,636950047	0,646295478
2nd Order Polynomial	0,637460523	0,655150819	0,612318469
3rd Order Polynomial	0,663877277	0,663631443	0,702978245

The accuracy of the land-cover classification results did not meet the requirements mentioned by Aronoff [12], which says that the accuracy at least 85%. However, this study was limited to the assessment of the best algorithms to produce land cover maps. Some other factors that lead to the low accuracy were also identified, and three of them were the presence of cloud cover, differences in image recording, and rotation of rice planting. Thin clouds have almost the same digital value as asbestos and zinc surfaces object. In addition, samples taken in the field which are then plotted on the image are often under the cloud in Landsat 8. So that it affects the accuracy of the object when conducting the accuracy-test results of multispectral classification. Rice planting rotation directly affects moist soil and moist and wet surfaces. These two objects are almost the same in the imagery, the difference is that moist soil has a brighter hue and is associated with broad woody leaves 3. Moist open land in the field can be found in post-harvest paddy fields and before planting rice seeds. Dark hue on damp objects and wet surfaces indicate that there is water on the object, besides that the damp open ground objects are side by side with broad, woody leaves 1 so that sometimes on land A rice is already mature while on land B rice is still newly planted and inundated by water. It is known that in the Dry Season (MK) of 2018, the first planting period is carried out in the third week of March to the first week of April. Whereas Sentinel-2A imagery being recorded on May 4, 2018, so that the average paddy is 1 month old. So that the condition of the object in the interpretation of the image is different from the conditions in the field. especially Landsat 8 imagery was recorded on May 29, 2016, the differences of recording condition with field conditions differed 3 years so that the land cover condition changed a lot.

4. CONCLUSION

From the three geometric correction methods, i.e. affine, 2nd order polynomial, and 3rd order polynomial the 3rd order polynomial method produces the smallest RMSE with a value of 0.100343. The polynomial order level is the parameter that most determines the Root Mean Square value of the geometric correction error. However, a small RMSE value does not guarantee that the image has good quality on the spectral dimension. This is evidenced by the second order polynomial resulting in the classification accuracy of the lowest land cover with an accuracy of 68.0590% in resampling with the nearest neighbor algorithm. The choice of the resampling method for each geometric transformation will affect the value of the output pixel. The new pixel value interpolated using the nearest neighbor algorithm on order-3 polynomial transformations and affine transformations produces land cover maps with the highest overall accuracy value compared to the bilinear interpolation and cubic convolution algorithm.

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