

# USING IMAGE FUSION AND CLASSIFICATION TO PROFILE A HUMAN POPULATION; A STUDY IN THE RURAL REGION OF EASTERN INDIA

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## ABSTRACT

With the recent advancements in image processing techniques and the increasing availability of high resolution satellite imagery, one has an increased ability to characterize human attributes. This paper will study the effects that image fusion has on the classification of Quickbird satellite imagery over a rural area in Eastern India. Two panchromatic sharpening algorithms will be used and compared to a classification of a single multispectral image to study the effects that image fusion has on image classification. Using the enhanced imagery an analysis into the prominent features like buildings, roads, agriculture, and water will be performed to characterize and better understand the human profile and lifestyle of the local population.

**Keywords:** high resolution satellite imagery, fusion, classification, human profile

## INTRODUCTION

This project was developed to bring a quantitative analysis and human understanding to a particular region of interest in a third world country. For this project an area in Eastern India was chosen that is in the State of Orissa and contained in the Nayagarh and Khorda regions. High Resolution (HR) Quickbird panchromatic (PAN) and Multispectral (MS) images were used, along with, administrative layers depicting the state and regional boundaries in India.

The image fusion portion of this project will attempt to answer the question of whether or not pan sharpening will improve the results of an image classification for roof pixels associated with dwellings in Eastern India. The process will consist of performing a pan sharpening image fusion between a HR PAN satellite image and a HR MS image from the same satellite. Two different image fusion methods, Ehlers Fusion and Subtractive Resolution Merge (SRM), will be analyzed and compared to a classification of the original MS image. The accuracy of the classification will be determined by accessing the amount of correctly classified pixels in several randomly selected locations in a densely populated neighborhood in the region. The underlying hypothesis of image fusion and classification is that PAN sharpening should improve classification of roof pixels compared to a classification of a single MS image.

The “human” analysis portion of this project will address the layout of different villages or neighborhoods with the prominent features of this region. The analysis will attempt to bring a human element to the table based on image characteristics such as roads, water, agriculture, terrain, and land cover and combine that with basic research into the local area based on the cultural characteristics for this region. The objective is to gain an understanding of the local people and region from an evaluation of imagery and geo-enabled administrative data.

## LITERATURE REVIEW

### Image Fusion

Observations from satellites, such as Quickbird, provide two different types of images, ie. PAN and MS. The PAN image has high spatial resolution but poor spectral resolution, while the MS image has low spatial resolution but high spectral resolution. A high spectral resolution helps in the discrimination of land cover types while a high spatial resolution image is used to determine boundaries of objects and shapes. Image Fusion can combine a high

spatial resolution PAN image with a low spatial resolution MS image to create a new MS image with high spatial resolution (Li and Li, 2010). While a lot of research has been done on developing algorithms for different fusion techniques not much work has been done on the effect of fusion on successive applications like image classification (Li and Li, 2010). Several different types of image fusion techniques exist for combining a PAN and MS image, including Brovey Transform (BT), Modified Intensity-Hue-Saturation (M-HIS), Principal Component Analysis (PCA), High Pass Filter (HPF), Smoothing Filter-based Intensity Modulation (SFIM), Wavelet transform, Ehlers Fusion, (Li and Li, 2010) and Subtractive Resolution Merge (SRM) ( Zheng Rong-er , Jie, Yi, and Tingwei, 2008).

The SRM fusion method was chosen for this project because it is based on a fairly new concept of combining image segmentation with a RGB color analysis to group pixels into like categories. The color model is based on mixing colors of cyan, magenta, yellow, and black to form other colors. Additional colors are added to the scene based on the “brightness” of MS value for that color. The resulting fused image is more color diverse based on measurements in the MS image (Zhang, Wang, Chen, Zhang, 2005).

The Ehlers Fusion method was developed to specifically address preserving spectral image characteristics when combining with a HR PAN image. The principle idea being the HR image has to sharpen the MS image without adding new gray level information to its spectral components. The Ehlers method should enhance high frequency changes such as edges and high frequency gray level changes in an image without altering the MS components in homogeneous regions (Ehlers, 2004). To do this Ehlers method combines a standard IHS transform with fast Fourier transform filtering of both the PAN image and the intensity component of the MS image (Li and Li, 2010). The Ehlers method was chosen for this project because it combines the best parts of several existing algorithms to address the shortfalls of each of those methods.

Other approaches to classification and feature extraction of remote sensing images involve classification of HR PAN images in urban areas using morphological and neural approaches. This work combines image segmentation with edge detection and region growing to make use of how features are oriented amongst each other instead of strictly using feature boundaries (Benediktsson, Pesaresi, and Arnason, 2003). A very recent study conducted by the University of Mississippi suggests that information extraction from HR imagery is sometimes hampered by the limited number of spectral channels available from the systems and that standard supervised classification algorithms found in commercial software packages may misclassify different features with similar spectral characteristics; leading to a high occurrence of false positives (Momm, Gunter, and Easson, 2010). To counteract this authors use object geometry to group like pixels in subsequent images, before and after hurricane Katrina. The draw back with this approach is that it relies on two datasets with one complementing the other, and in a general sense these datasets may not always be available for every area of interest.

## **Settlement Morphology**

The concept of settlement morphology was chosen to bring a “Human” aspect to the project. The idea is to look at some basic layouts of different neighborhoods in this region and characterize the main physical attributes that go into how the neighborhoods are laid out. For example, where the roads are in relation to where the houses are, is there a reason that the neighborhoods are located where they are, and what does the local land cover say about how the neighborhoods were formed. To this end the following studies were reviewed related to this topic.

A current flagship study on this topic entitled “Introduction to the Issue on Remote Sensing of Human Settlements: Status and Challenges” were the authors suggest a quantitative evaluation of the physical properties of a given area, including land covers, material status, and land usage (Gamba, Tupin, and Weng, 2008) was reviewed. The report displays some innovative researches going on in this field and provides an overview of the state-of-the-art, along with, describing some of the challenges going forward. A key conclusion of the study was that more work on classifying HR imagery is needed due to the high spatial and spectral resolutions. Along these same lines, a paper discussing global trends in the remote sensing of human settlements (Forster, 2010) was reviewed. The study presents a brief history of the topic, examines the properties of current remote sensing systems and their acquired data, and presents some processing methods and urban applications.

An integrative assessment of informal settlements using HR remote sensing data was conducted in the Delhi area of India (Niebergall, Loew, and Mauser, 2008). The study investigates the potential to use HR remote sensing data to identify urban structures and dynamic within the Delhi region. The paper presents a semi-automated, object oriented classification approach which allows for the identification of informal settlements within urban areas. The goal of the study is to provide indicators to identify socio-economic structures and their dynamics. Information on population and water related parameters are derived.

A study in Central Canada used SPOT XS imagery to map exurbanite residential developments on the assumption that individual sites, under current development, possess a unique spectral signature (Brunger and Treitx, 1987). The satellite imagery was cross referenced with topographic maps and aerial photos and found to

reduce classification error. Extraction of urban settlements using an automatic approach on HR IKONOS imagery was performed (Tarantino et. al, 2003). The authors performed a maximum likelihood pixel classification on PAN sharpened imagery (1-meter resolution) to analyze changes in urban areas. Another study looked at population distribution characteristics and patterns based on remote sensing and GIS in a mountainous region in China (Shuwen et. al, 2006). A key conclusion is that population distribution is disperse and diverse in this region and that agriculture production is dominant.

## **METHODOLOGY**

The image fusion portion of this project was developed to study the effects that pan sharpening image fusion has on the classification of roof pixels for structures in a densely populated neighborhood in the Nayagarth Region of Eastern India. The processes consisted of cropping a local area of interest from the larger dataset, and performing a pan sharpening between a PAN image and a MS image from the Quickbird satellite. Two different fusion algorithms were used, the Ehlers Fusion algorithm and the SRM algorithm. Once the pan sharpening was completed a two different classifications were performed, sub-pixel identification and a fully supervised maximum likelihood classification was performed on each image, along with a classification of the original MS image. The sub-pixel identification approach just classified the pixels that were the same in a single training category (roof), whereas, the fully supervised classification classified 10 categories of pixels based on training classes for vegetation, agriculture 1-4, water, paved road, dirt road, structure (roof), and shadow. The results were compared between the 3 images for both classification methods based on a visual interpretation of correctly classified roof pixels for 10 random buildings in the neighborhood. A vector shape file of the 10 roof outlines were created from the PAN image, once the classifications were complete the same shape file was used with the 3 classified images to estimate a percentage of correctly identified roof pixels. The objective of the roof classification is to automatically determine what areas in the image contain structures and to study what that layout can tell us about the people and culture in this region. The ERDAS Imagine software package was utilized to perform the image fusion and subsequent pixel classifications.

The settlement morphology and cultural analysis portion of this project consisted of measuring the vegetation, roads, structures, and water areas in two different neighborhoods of a rural area in the State of Orissa, Nayagarth Region, in Eastern India. The measurements were taken using ArcGIS with the sites being labeled one and two. Once the measurements were taken, data analysis was conducted to analyze what the spatial relationship between the features can reveal about the people who live here. Features such as geography, population, agriculture, transportation networks, and industry were analyzed in the imagery to gain an understanding of the local region. To facilitate the analysis administrative layers were used to help understand where the local area of interest falls in relation to the larger structure of the country in general. Once a general area was determined, based on India's cartographic and political layout, some basic research into the people and region was conducted to confirm the assumptions based on the imagery and to provide more detailed profile of the local population.

## **DESCRIPTION OF DATASETS**

The datasets used for this project consisted of a 65cm resolution PAN image and a 2.5 meter resolution MS image from the Quickbird satellite. Both images were taken on December 11, 2004 and were found at the website of the Global Landsite Facility at the University of Maryland, College Park. The images are of an 11km by 11km area of Eastern India in the State of Orissa, in the Nayagarth and Khordha regions, just north of Chilka Lake and close to the shoreline of the Bay of Bengal. This area is very rural and appears to be focused around agriculture with the villages or neighborhoods being very compact and densely populated.

Administrative layers (Diva-GIS, 2011) containing state and region boundaries were used and geo-referenced to the imagery to provide an understanding of where the local project site falls in relation these higher level boundaries recognized by the country. Table 1 contains the bounding geographic coordinates for this dataset.

**Table 1.** Geographic Coordinates for Area of Interest

Corner	Latitude (DD.MM.SS)	Longitude (DD.MM.SS)
Northwest	N 20.00.32	E 85.16.32
Northeast	N 20.00.32	E 85.22.56
Southwest	N 19.54.25	E 85.16.32
Southeast	N 19.54.25	E 85.22.56

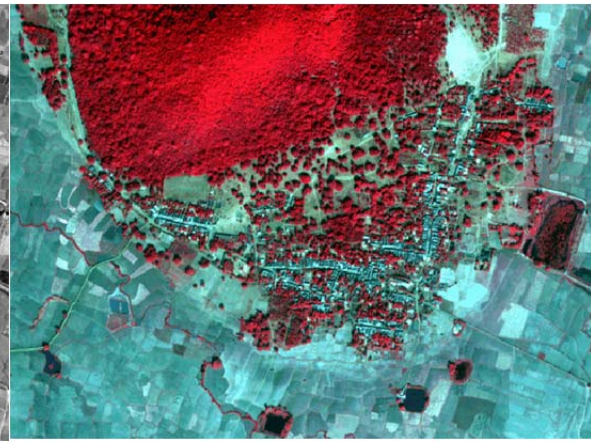
## DATA ANALYSIS

### Image Fusion

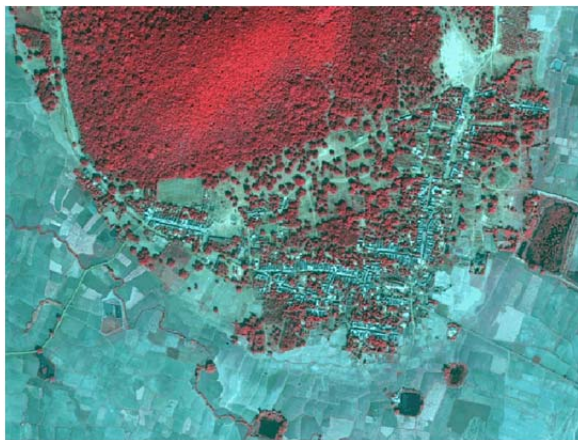
Since the original Quickbird satellite image is large, 11km by 11km, cropping was used to isolate one of the larger neighborhoods. This neighborhood was selected because it had many housing structures, vegetation, several different kinds of agriculture fields, and roadways. The Ehlers Fusion and SRM Fusion algorithms were used to develop the “fused” images. Figures 1-4 depict the original PAN and MS images along with the resulting fused images.



**Figure 1.** Original PAN Image



**Figure 2.** Original MS Image



**Figure 3.** SRM Fused Image

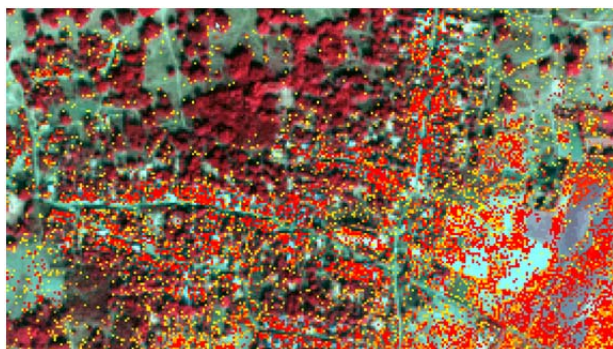


**Figure 4.** Ehlers Fused Image

The fused images both have increased spatial and spectral resolution as a result of the pan sharpening operation. The Ehlers Fusion has retained more of the original MS spectral characteristics where the SRM image appears somewhat washed out, most likely, the result of retaining more characteristics from the PAN image. Once the pan sharpening was performed the images were classified using the sub-pixel classifier according to the selected training



dataset. The same training dataset was used for both images. Figures 5-7 depict the results of the sub-pixel classification for each fused image.



**Figure 5.** Original MS Image Sub-Pix Class



**Figure 6.** Ehlers Image Sub-Pix Class



**Figure 7.** SRM Image Sub-Pix Class

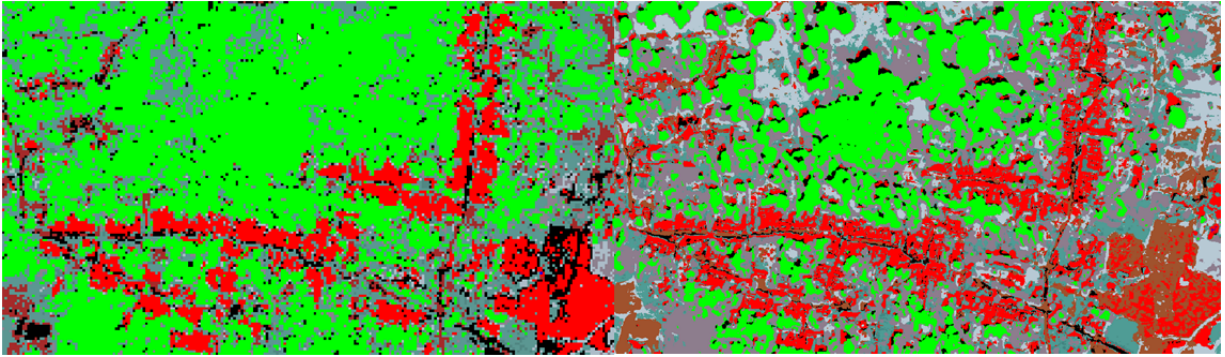
Note the large amount of false positive results of pixels being classified as roof. After the sub-pixel classification was completed and analyzed a fully supervised maximum likelihood classification was performed to investigate whether or not this approach could improve the sub-pixel classification results. Figure 8 shows the training classes that were used to develop the supervised classifications with the same training classes being defined for the MS, Ehlers, and SRM images.

Class #	>	Signature Name	Color	Red	Green	Blue	Value	Order	Count
1		VEGE		0.000	1.000	0.000	1	1	202453
2		AG1		0.314	0.612	0.586	2	2	38483
3		AG2		0.721	0.792	0.833	3	3	6008
4		AG3		0.555	0.493	0.553	4	4	2187
5		WATER		0.000	0.000	1.000	5	5	2935
6		AG4		0.260	0.528	0.512	6	6	5218
7		ROAD-PAVED		0.000	0.000	0.000	7	7	227
8		STRUCTURE		1.000	0.000	0.000	8	8	763
9		ROAD-DIRT		0.627	0.322	0.176	9	9	103
10	▶	SHADOW		0.000	0.000	0.000	10	10	110

**Figure 8.** Fully Supervised Training Classes

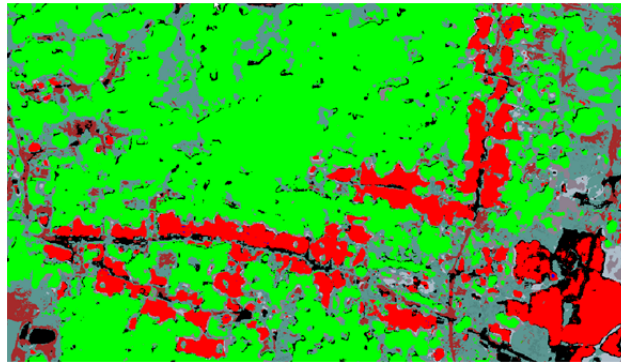
The training classes were chosen based on multiple representative samples for each category, with special attention to only include “pure” pixels in each group. The results of the fully supervised ML classification are contained in Figures 9-11. Note the differences in the roof structure classifications (red pixels) in each image. Each image contains a large amount of false positive hits, with the Ehlers image producing the least among the 3.





**Figure 9.** Original MS Fully Supervised Class

**Figure 10.** Ehler's Fully Supervised ML Class



**Figure 11.** SRM Fully Supervised ML Class

### Settlement Morphology

Two sites were picked to analyze settlement morphology and the subsequent “human” interpretation based on the image analysis. Each of the sites is similar in size and in the same general region. Figures 12 and 13 depict the neighborhoods with the roadways measured in brown, the vegetation outline in green, the housing structures in yellow, and the water ponds in blue. The measurements were made using the SRM fused image but overlaid on the PAN image to highlight the different colors.



**Figure 12.** Neighborhood #1



**Figure 13.** Neighborhood #2

## RESULTS

The image fusion between the Quickbird PAN image and the MS image was successful using the Ehlers and the SRM pan sharpening algorithms. The fused images provide some definite advantages for combining high spatial and high spectral resolution imagery. One major difference between the fused images and the original MS image is the pixel resolution, where the fused images have a 65 cm resolution compared to the original MS image at 2.5 meters. Consequently, this resulted in different pixel classifications for each image based on the roof training class. A sub-pixel classifier was used to identify all of the pixels in the image that are of the same category of roof training class. Table 2 summarizes the percentage of correct pixels, based on 10 randomly selected roof structures spread throughout the scene, for each original MS image and each fused image. Table 3 shows the percentages of incorrectly identified pixels, based on a different 10 random locations spread throughout the scene. The percentages were estimated by visual quantitative analysis of each area.

**Table 2.** Percentage of Correctly Identified Pixels

Location	Original MS Image	Ehlers Fusion	SRM Fusion
1	55	95	80
2	60	95	80
3	45	90	70
4	90	95	85
5	80	95	90
6	60	80	50
7	60	50	55
8	40	95	75
9	85	95	65
10	20	80	10
<b>Average % Correct</b>	<b>60%</b>	<b>87%</b>	<b>66%</b>

**Table 3.** Percentage of IN-Correctly Identified Pixels

Location	Original MS Image	Ehlers Fusion	SRM Fusion
1	80	90	85
2	85	70	80
3	5	60	5
4	75	55	0
5	0	0	0
6	70	50	5
7	5	0	0
8	0	10	0
9	0	5	5
10	0	0	0
<b>Average % IN-Correct</b>	<b>32%</b>	<b>34%</b>	<b>18%</b>

Table 2 indicates the Ehlers Fusion algorithm outperformed the SRM method and the original MS image by a significant margin, based on the average percentage of correctly identified pixels. The SRM method did marginally better than the original MS image, even though the spatial resolution is much better. It is important to remember the fused images have a pixel resolution of 65 cm, whereas, the original MS image is at 2.5 meters. So, it is conceivable

that some pan sharpening algorithms might not perform as well, on a classification basis, as an image that has not been sharpened. Table 3 indicates the percentage of pixels that have been in-correctly identified, with the SRM method performing the best. Notice the original MS image and the Ehlers Fusion method resulted in about the same percentage of incorrectly identified pixels, even though the spatial resolutions are quite different. Taking into account the percentage of correct pixels minus the percentage of in-correct pixels resulted in an “adjusted performance” value summarized in Table 4.

**Table 4.** Adjusted Performance

	<b>Original MS Image</b>	<b>Ehlers Fusion</b>	<b>SRM Fusion</b>
<b>“Adjusted Performance”</b>	<b>28%</b>	<b>53%</b>	<b>48%</b>

The adjusted performance still shows the Ehlers algorithm performing better but is much closer to the SRM method when taking correct and in-correct pixels into account. In this case both the pan sharpened images outperformed the original MS classification by a noticeable amount.

After the sub-pixel classification was complete an attempt to improve the classification results based on a fully supervised maximum likelihood (ML) classification was investigated, as depicted in Figures 9-12. The training classes were designed according to Figure 8 and were the same for all of the images. The thought here was that most of the false positive hits came on agriculture field areas and if several more classes were specified in these areas that maybe the roof classification could be improved. The roof pixels are shown in red and even after the ML classification there were a significant number of false positive hits. Note the southeast corner of Figures 9 and 11 where the agriculture field is classified as roof, whereas, the Ehlers method shows the majority of these same fields being correctly identified as agriculture pixels.

### **Image & Cultural Analysis**

To analyze settlement morphology in each image some major attributes, including roadways, vegetation, agriculture, housing, and water areas, were located and measured in the pan sharpened imagery. This fused image (SRM method) provided an advantage over the original MS image because of the increased spatial detail while maintaining the spectral information in the MS image. The following analysis was developed based on two categories of information, image analysis and basic research of the region in general. The latter being the result of the administrative layers obtained that facilitated the understanding of where and how this area of interest is referred to by the people of India.

**Geography.** The settlements used for this project are located in the Nayagarh district, State of Orissa, in Eastern India. They are located towards the west of Puri district surrounded by Cuttack district in the North, Phulbani district in the West, Ganjam district in the South and Khurda district in the East. The District of Nayagarh lies between 19 degrees 54 minutes to 20 degrees 32 minutes North latitude and 84 degrees 29minutes to 85 degrees 27 minutes East longitude. This district is situated in the hilly ranges in the West and its northeastern parts have formed small well cultivated fertile valleys intersected by small streams. This district is at a higher altitude than sea level so the potential for flood events is decreased compared to some of the surrounding Districts. The Mahanadi River flows along the Eastern boundary with the Khurda district (District of Nayagarh, 2010).

**Agriculture/Landuse.** The majority of the surrounding land cover is being used for agriculture purposes, which includes extensive and intricate farming practices. From the imagery, once can conclude that the different spectral colors correspond to different types of crops, soil, and moisture content. It is also important to note that the majority of the scene (area) is devoted to agriculture purposes, with the usable land being maximized for farming. Several areas show the planned removal of vegetation to maximize crop area, as evidenced by geometric clearing lines. This indicates that farming is very important to these residents and contributes to a large part of the economy in this region. Another indicator of the importance of agriculture in this region is the intricate design of irrigation ditches around each crop. Over 76% of the people in the State of Orissa are dependent on agriculture for their livelihood. The cropped area of the state is approximately 8,750,000 square hectares with the majority being irrigated to grow rice, pulses, oil-seeds, jute, mesta, sugarcane, coconut and turmeric. Overall, the State of Orissa contributes one-tenth to the total rice production of India (State of Orissa/Rural Development, 2010).

**Roadways.** The majority of roadways in this region are non pavement dirt roadways that snake through the settlements, fields, and crops. It appears the roadways take the path of least resistance which would be typical of a system that has originated over time and not built and engineered at one time with formal construction services. The small numbers of roads in this region indicate there are not a lot of places to go other than the settlements and out to



the main highways. One can infer that the roads play an important role for the livelihood of the people because of the amount of agriculture and the need to get farming supplies/equipment in and crop yield out to sell.

**Vegetation.** The vegetation in this region consists of trees and ground cover bush that are growing around wet areas, higher altitude mountainous or hilly areas, and the settlements. The mountainous areas are fully vegetated while the lower flat areas are mostly open and being used for agriculture purposes, indicating again how important the agricultural industry is for these people. The creeks and rivers that feed the irrigation ditches are vegetated and help visualize the path of the river across the region. Another interesting phenomenon of the vegetation in this region is that it grows around the settlements, or, the settlements were built to coincide with the vegetated areas. This is most likely because vegetation provides a natural shelter from strong wind, sand storms, rain, and offers shade from the sun.

**Water wells.** Most of the neighborhoods contain water wells that are close to the settlement structures. The average size is approximately 60 meters in diameter and there is usually one for each neighborhood area. The roadways to and from these wells appear to be in constant use, as evidenced by the fresh dirt on the road surface. The presence of wells most likely indicates the lack of a sophisticated plumbing infrastructure, as is the case in more rural and un-developed areas.

**Settlements.** The settlements structures in this region are long and wide, averaging approximately 5 meters wide by 15 meters long, and built very close together. These settlements contains a long structure parallel with the road and many long skinny structures built behind it that are perpendicular to the road, most likely, the front is a common area and the back are more private family areas. The settlement is laid out either side and very close to the roadway, indicating the road is of high importance and a main focus in servicing this settlement. Most likely, the road provides a means for survival to this village, servicing the agriculture needs, export/selling agricultural yields, providing access to medicine and medical care, and allowing people to procure other modern conveniences. The footprint of the settlement on the ground looks to be minimized to service the agriculture industry, which is indicated by the agriculture fields being built right up to and around the settlement. Also, the residents of the village are probably the ones that farm the fields since there is no separation between the village and the fields. The settlement is fairly isolated with the closest neighbor being a small village about 1 km east and the closest small city, Chandpur, being approximately 9 km southeast.

**Population.** According to the 2001 country census, India's Nayagarh district has a total population of 132,644 people with 69,115 being men and 63,529 women. In addition to the general population the State of Orissa recognizes two other classifications of people, scheduled casts and scheduled tribes. Scheduled casts make up 14,960 people total with 7598 men and 7362 women. The scheduled tribes make up a much smaller population with 621 total people with 325 men and 296 women. The working population was also captured in the census and consists of 40,230 total workers with 36,993 men and 3,237 women. The non-working population is 92,414 total people with 32,122 men and 60,292 women, (India Census, 2001).

**Food.** Cooked rice with dal and curry are the main meal for most of the people in the State of Orissa. Even the tribal people in the hilly regions who take millet and ragi as their staple food prefer a rice meal. In the more urban areas of the state some people have switched over to wheat in place of rice and use roti and chapati for cooking dinner. Rice as the main course can be prepared in a number of ways; the most common is with kanika which is cooked with ghee, sugar, and khechudi (State of Orissa/Food, Supplies, and Consumer Welfare, 2010).

**Language.** Oriya is the mother tongue of the people of Orissa and most of them understand Hindi as well. People can sometimes speak Bengali, Telugu, Urdu and a bit of Gujarati in addition to the various tribal dialects. English can only be understood by the educated masses (State of Orissa/Government Portal, 2010).

**Religion.** Of all of the states of India, Orissa has perhaps the highest concentration of Hindus. In 1971 the Hindus formed 92 per cent of the total population; the Muslims, Christians and Buddhists formed 1.5, 1.7 and .04 per cent respectively. The balance is primarily tribal religions of Sarana and Santals. Orissa is a land of religious tolerance and the people belonging to different religions and faiths live harmoniously, often within the same village (State of Orissa/Government Portal, 2010).

**Industry.** Industry also plays a key role in the economy. Products manufactured in Orissa include textiles, paper, leather goods, cement, soap, glass, aluminum, and flour. Some of the natural resources that are mined are iron, coal, and zinc. Orissa has trade relations with other states in India, the United States, Japan, Britain, and Germany. There are many products that are shipped in and out of Orissa annually with the main exports being expensive gems, fish, fancy jewelry, baskets, and clothing. Orissa is known worldwide for its fine cloths and the painstaking effort with which they are made (State of Orissa/Industries, 2010).

## CONCLUSIONS

The image fusion part of the project investigated the hypothesis of whether or not pan sharpening image fusion of Quickbird satellite imagery would improve a subsequent pixel classification of roof structures. The results confirmed the hypothesis but also brought to light several challenges that were associated with this process. First, the image size and computer processing power directly impacts whether or not some of the fusion algorithms can be used on a practical basis. For example, the images used in this project had to be cropped down from the original size because the Ehlers Fusion would take many hours to complete. Once smaller images were developed the algorithms ran smoothly taking about 20 minutes to finish. The fused images did provide an increased spatial and spectral resolution (65 cm) compared to the original MS image (2.5 meters) alone.

The fused images did outperform the original MS image but not as well as you would be led to believe based on just the correctly identified roof pixels. For example, the Ehlers algorithm showed an 87% success rate of correctly identified roof pixels, but, when you factor in the false positives the adjusted performance value decreased significantly to 53% for Ehlers and 48% for the SRM. However, both fused algorithms performed better than the original MS image and provide the user with an enhanced analysis capability due to incorporating the high spatial detail of the PAN image along with the high spectral resolution of the MS image.

Using fused classified imagery to conduct analysis and measurements of the prominent spatial features confirmed the hypothesis of whether or not understanding features like roadways, structures, vegetation, and agricultural/land cover uses could be used to gain information about the local people and the region. A subsequent analysis of geography, language, religion, food, and industry was conducted and supplied a significant amount of information about the local people and culture. Geo-enabled administrative layers such as state and regional boundaries helped facilitate this research and provided local knowledge of how the government refers to this part of the country. Together, the imagery analysis and the cultural research proved to supplement each other and helped to confirm the respective conclusions.

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