A Canopy Adjustment for Fractional Snow-Covered Area

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INTRODUCTION

Snow cover is an important reservoir of water supplying human and ecosystem needs, so accurate estimates of snow-covered area (SCA) are necessary for water supply forecasts. The high reflectivity of snow allows its extent to be effectively monitored by satellite remote sensing (Dozier, 1989). Painter et al. (2009) developed a method using spectral mixture analysis for detecting the fraction of each satellite image pixel that is snow. This method can accurately return the fractional snow-covered area (FSCA) in sparsely vegetated areas, but in regions of dense forest satellites cannot penetrate vegetation canopy to detect the underlying snow (fig. 1). This results in the systematic underestimation of snow (Nolin, 2010). The objective of this study is to use remotely sensed vegetation data to adjust satellite images of FSCA in the northern Oregon Cascades to account for the snow that is obscured by canopy cover.

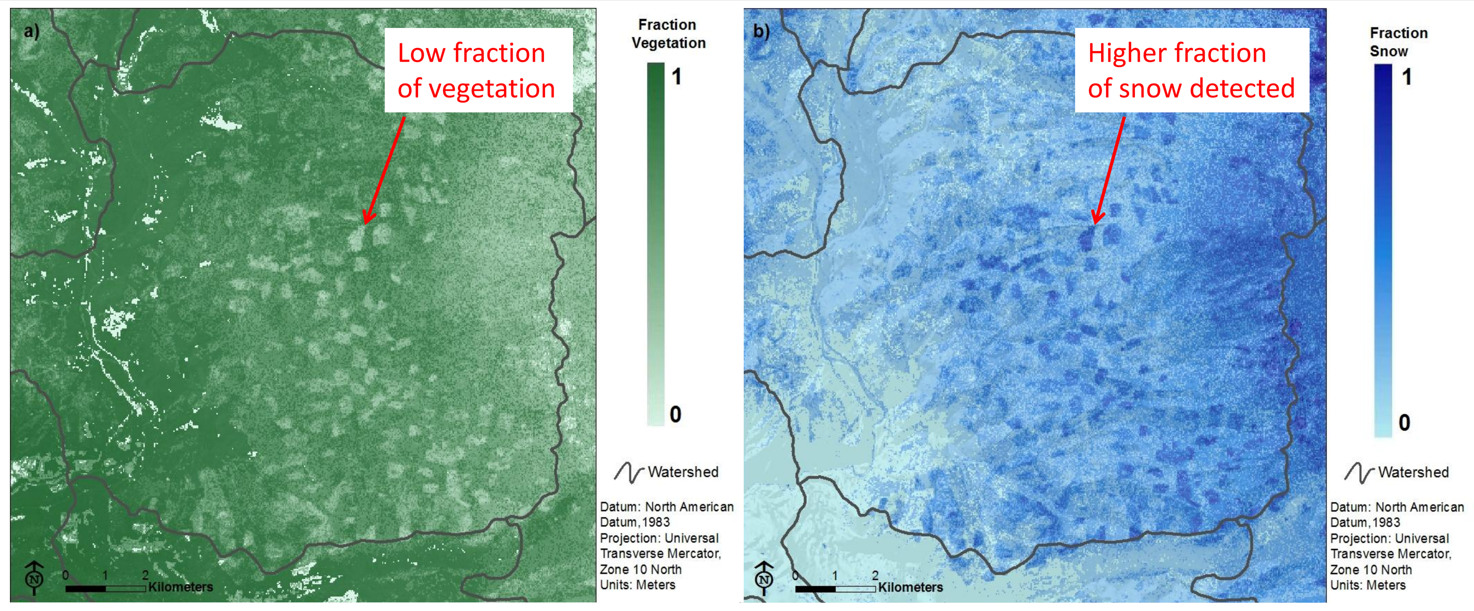

Figure 1. A mosaic of timber harvest clear cuts illustrate the relationship between fraction of vegetation cover and fraction of snow cover detected by Landsat. Areas with a lower fraction of vegetation (light green) have a higher fraction of snow cover (dark blue).

METHODS

ENVI Image Processing Software was used for preprocessing and re-sampling of the satellite imagery. The vegetation products were used to mask the fraction of vegetation that could be obscuring snow. The masked vegetation was then replaced with the same proportion of snow that was detected in the openings (fig. 3). Total percent area covered in snow was extracted by elevation band for the original and adjusted snow-covered area products using ArcMap 10. These results were then compared to unadjusted FSCA and the binary SCA.

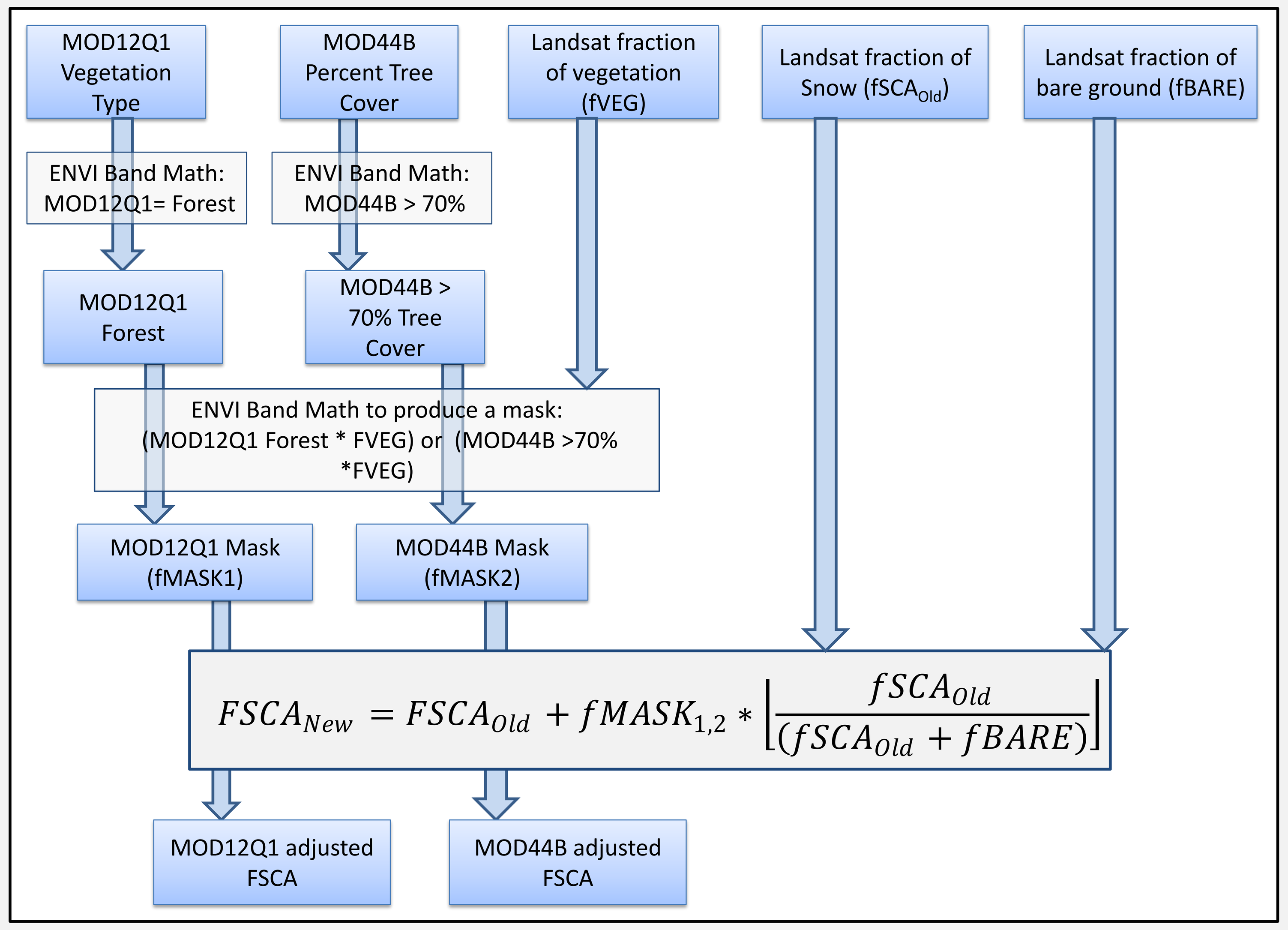

Figure 3. Flow chart indicating the steps performed to determine a canopy adjusted FSCA.

DISCUSSION AND CONCLUSION

The results of this analysis indicate that a considerable increase in the estimates of FSCA can be achieved by adjusting for canopy cover, but there is a high amount of uncertainty that must be considered. Atmospheric effects, cloud cover, and topographic shading affect the ability of satellites to accurately classify ground as snow or determine vegetation characteristics (Nolin, 2010). Also, the hypothesis that forest is the only vegetation type to obscure snow, the arbitrary threshold of 70 percent tree cover, and hypothesis that obscured SCA is equal to detected SCA introduce additional uncertainty. In situ observations are needed to improve and validate these adjustments as well as to quantify the associated error.

Canopy adjustments using vegetation characteristics to account for obscured snow have the potential for significantly improving estimates of SCA in densely forested regions, which represent a large proportion of the snow cover in the Oregon Cascades. Better SCA estimates will aid in monitoring snow accumulation and melt patterns, from the basin to regional scale, for hydrologic forecasting and monitoring.

REFERENCES

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Tom Painter provided the processed Landsat FSCA data. This research is supported through the MISR Science Team contract with NASA/Jet Propulsion Laboratory.

DATA PRODUCTS

To create an adjustment for FSCA sattelite-derived vegetation functional type and areal percent tree cover data were acquired (Table 1). A binary SCA product was also acquired for comparison. All data were clipped to the extent of the FSCA image (fig. 2) and resampled to the pixel size of the lowest spatial resolution product (500m).

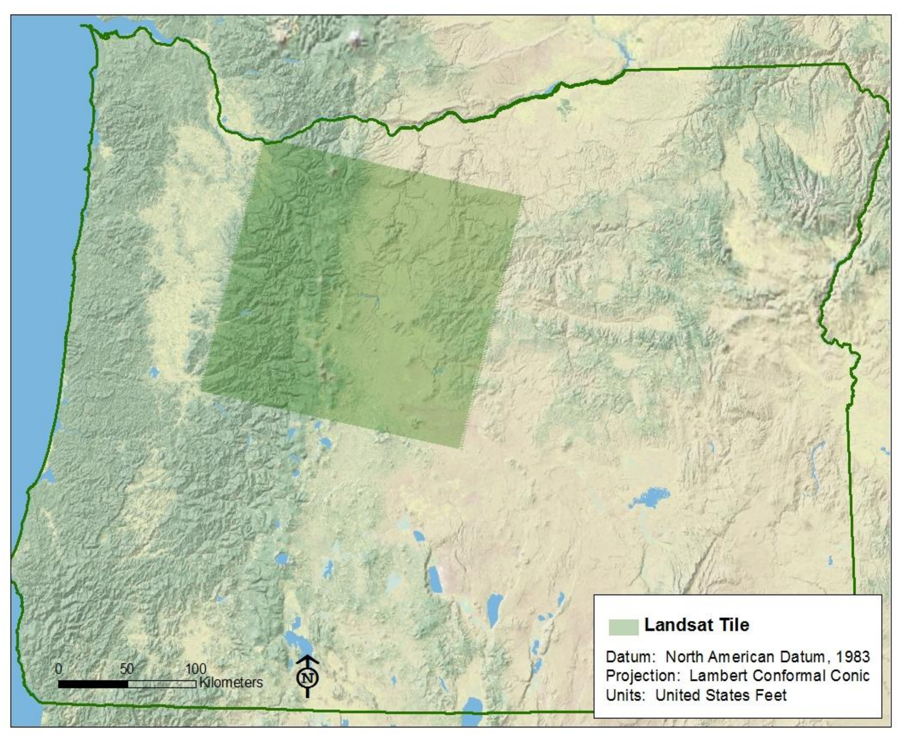

Figure 2. Location of the analysis study area in Oregon. The shaded green box indicates the extent of Landsat Tile, Path 45 Row 29 that was used to define the extent of the data products used in this study.

TABLE 1. Description of the remote sensing data products used in this analysis.

Data Product	Satellite Sensor	Spatial Resolution	Description	Role in this Analysis
Landsat FSCA	Landsat TM[1]	30 m	Fraction of each pixel that is snow, vegetation, or bare ground	Base fsca for adjustment
MOD12Q1	MODIS[2]	500 m	Landcover vegetation type	Mask for adjustment based on vegetation type
MOD44B	MODIS[2]	250 m	Percent tree cover	Mask adjustment based on percent forest cover
MOD10A1	MODIS[2]	500 m	Binary Snow Cover	Comparison with fractional estimates of snow cover

1. NASA's Landsat Thematic Mapper (The Landsat Program, http://landsat.gsfc.nasa.gov)
2. NASA's Moderate Resolution Imaging SpectroRadiometer (MODIS Web, http://modis.gsfc.nasa.gov)

RESULTS

There were considerable differences between the original FSCA and the canopy adjusted FSCA in the elevation bands with extensive forest cover and a high percentage of tree cover (fig. 4 and fig. 5). Both the canopy adjustment determined using the vegetation type (MOD12Q1) and percent tree cover (MOD44B) increased the overall SCA for the Landsat tile in Oregon. The adjustment using the mask based on vegetation type yielded a higher SCA, but was still lower than the binary snow product form MODIS. (Table 2).

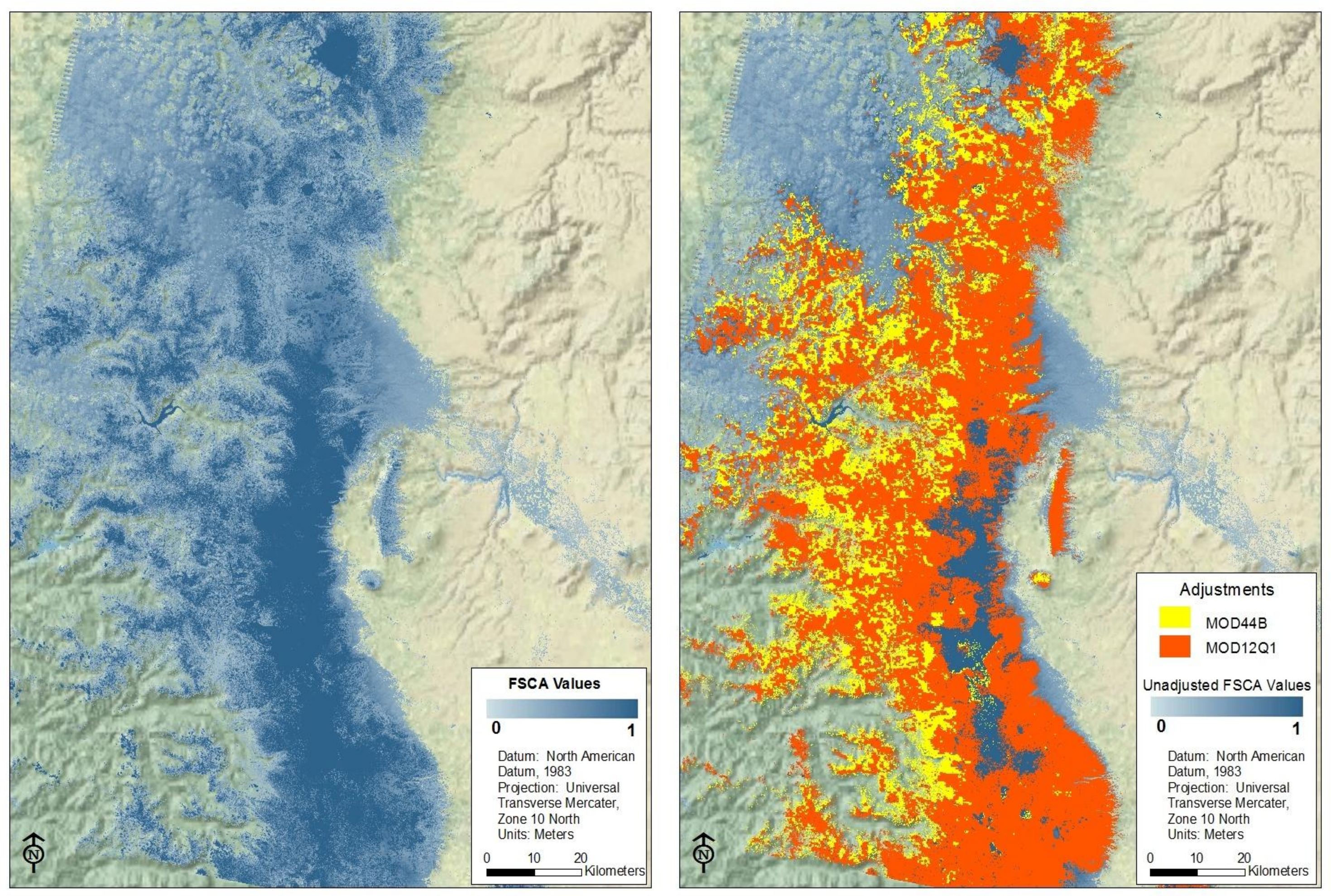

Figure 4. Original FSCA (a) and the two adjustments (b) using satellite vegetation data products.

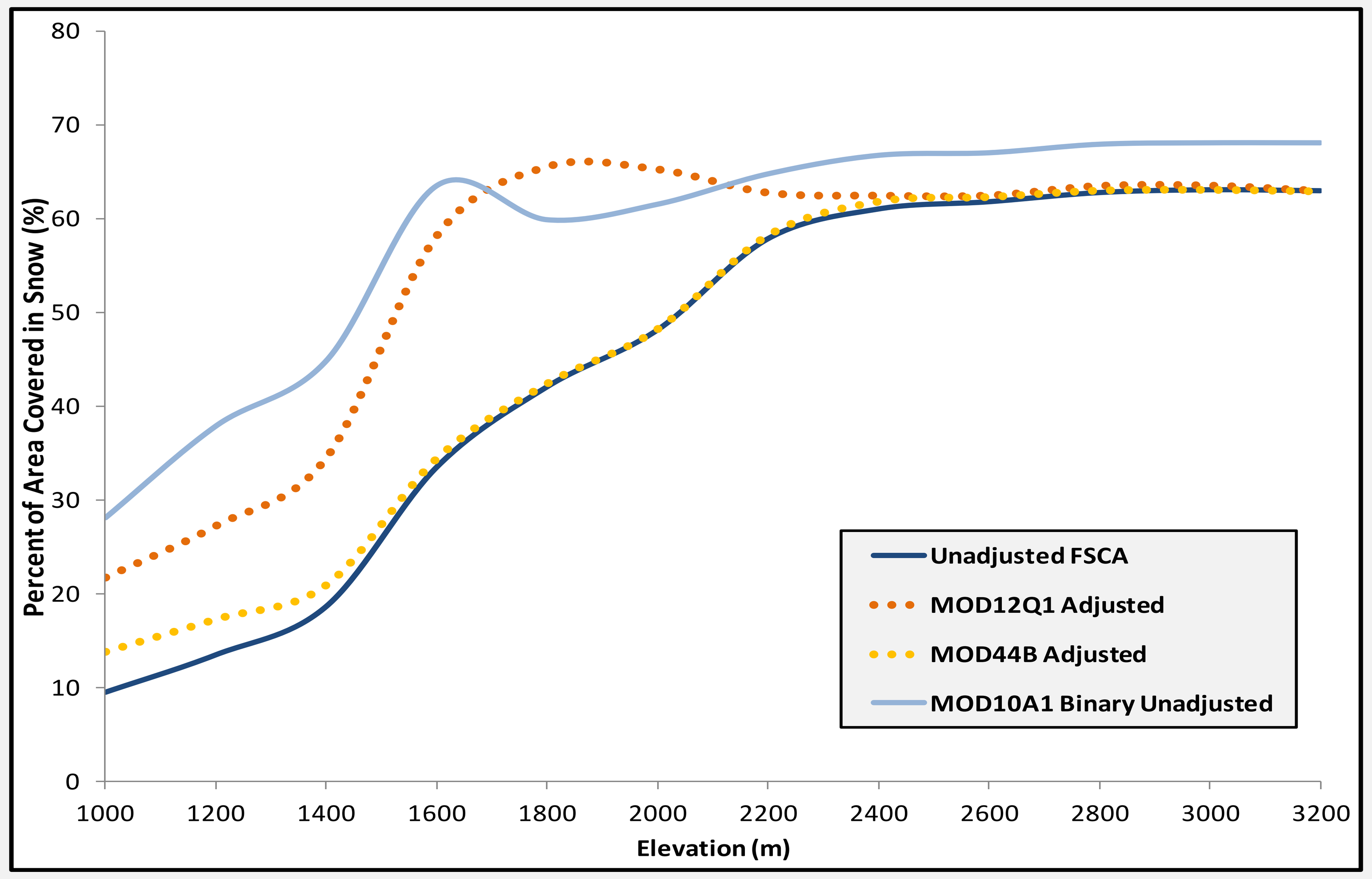

Figure 5. Total snow-covered area by elevation band for adjusted and unadjusted FSCA.

TABLE 2. The total SCA and percent snow cover for the entire Landsat tile

	MOD10A1 Binary	Landsat Unadjusted	MOD12Q1 Adjusted	MOD44B Adjusted
Total Snow-Covered Area	9,100 Km^2	3,750 Km^2	7,220 Km^2	4,550 Km^2
Percent of Total Area Covered in Snow	38%	16%	30%	19%