Interreg Alpine Space project - **NEWFOR**

Project number 2-3-2-FR

NEW technologies for a better mountain **FOR**est timber mobilization

Priority axis 2 - Accessibility and Connectivity

Workpackage 4: Forest resources & LiDAR

High resolution aerial images from UAV for forest applications

State-of-the-Art

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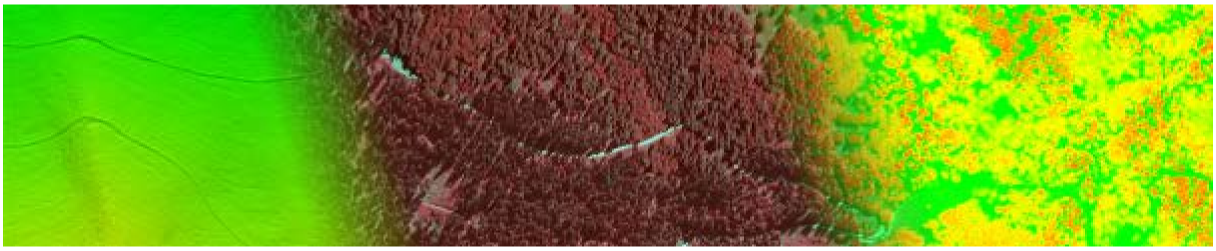

The consortium of the project Interreg Alpine Space NEWFOR

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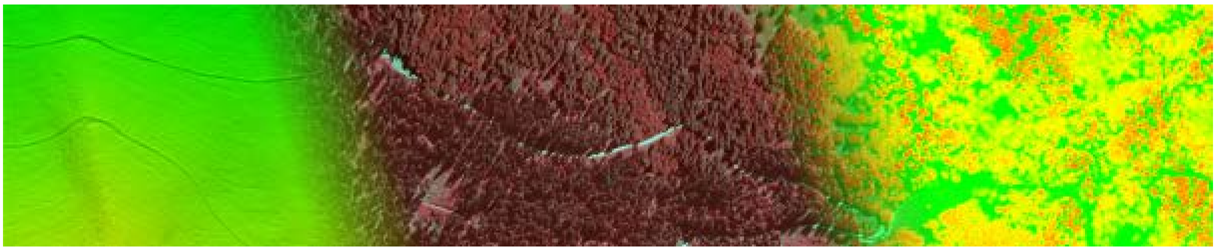
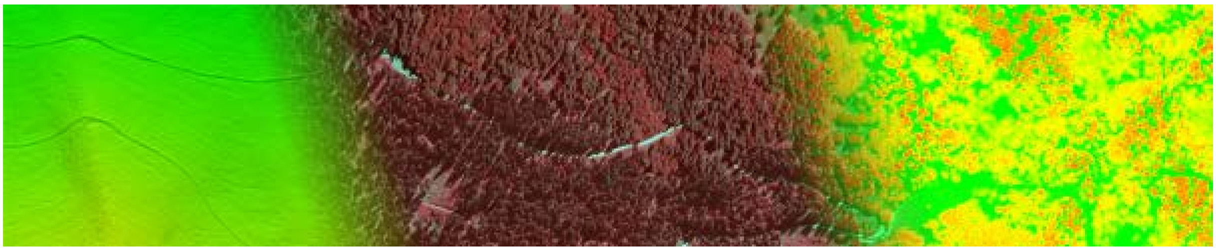


1 CONTENTS

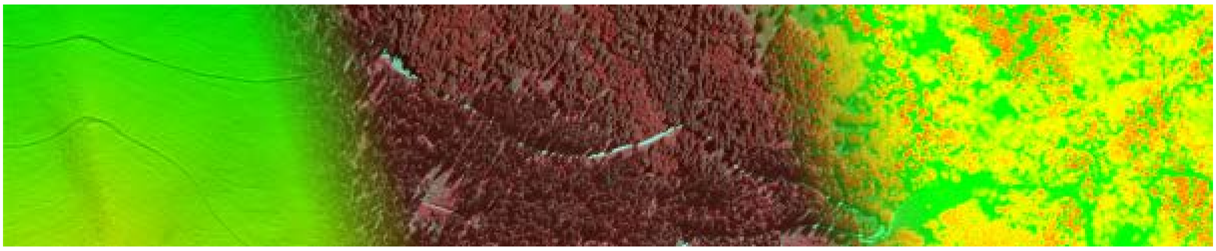


2 ABSTRACT

Unmanned aerial vehicles (UAV) are a rapidly upcoming method for remote-sensing data acquisition, mostly aerial images and derived products. By now, the systems are light-weight and cost-effective, the development and miniaturization of the sensors and their reliability enable a relative safe operation with good chance of success. UAV´s are quickly ready for operation almost everywhere and every time.

One of the greatest advantages of this new technique is its high flexibility and the relatively low operational costs. The miniaturisation of the sensors and the increasing reliability of the navigation systems make UAV´s to an instrument for operational applications. In contrast to standard aerial imagery, the better resolution of the data offer possibilities for new developments in image analysis.

Technical limitations can hinder the acquisition of images, especially in remote and steep (forested) regions. For fixed-wing UAV´s suitable landing places are required. Narrow, rough forest roads or clearings are often the only possibilities in dense forested areas, but bear a high risk of damage. In case of no or low-quality GNSS signal, a manual flight control can be essential, with all drawbacks for image processing (overlap, area coverage, high rotational and angular deviations, oblique images, no exterior orientation parameter (EOP)). Without EOP, the automated image matching process may be impossible, because of the lack of clearly defined features. Furthermore, ground control points often are simply not visible, hard to establish and / or measure with reasonable accuracy.



3 UAV – TECHNOLOGY

3.1 INTRODUCTION

Unmanned aerial vehicles (UAV) are a rapidly upcoming method for remote-sensing data acquisition, mostly aerial images and derived products. By now, the systems are light-weight and cost-effective, the development and miniaturization of the sensors and their reliability enable a relative safe operation with good chance of success. UAV´s are quickly ready for operation almost everywhere and every time. Limitations – specially in mountainous and forested environments - result mainly from weather conditions (wind!), visibility, availability / existence of landing sites, GNSS signal quality and last but not least legal constraints.

3.2 UAV DESIGN

A variety of flying vehicles is able to transport cameras and / or other sensors. Most common forms are small, electrically powered model planes with wingspans from 2 – 3 meters and multi- bzw. helicopter. They are piloted by an operator via RC, assisted by an autopilot onboard (Fig. 1). Also often used are gas ("lighter than air platforms") or hot air carried platforms like balloons, aerial kites and paraglide with or without motor (Aber 2010).

Fixed-wing UAV "FPVRaptor", BFW

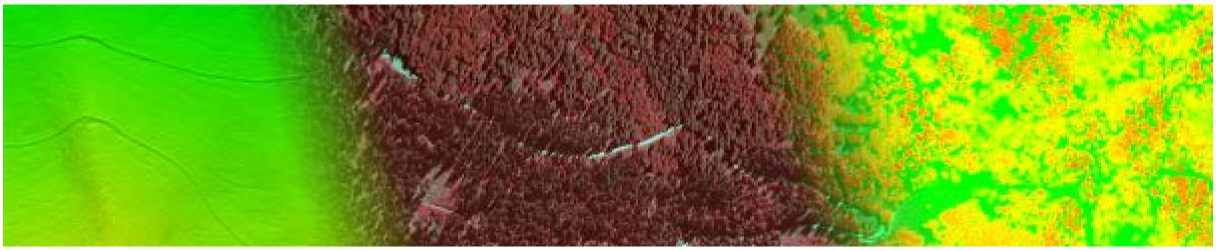
(www.bfw.ac.at)

Hexacopter from twins.nrn *(www.twins.co.at)*

Figure 1: UAV platforms

3.3 NAVIGATION

Autopiloted UAV´s are navigated by a small onboard GNSS/INS-unit. The main components of the navigation unit are gyroscopes for measuring roll, nick and gear angles of the platform, air pressure sensor, magnetometer and accelerometer (Böhm 2010, Aber 2012). At the ground station, the mission planning is prepared and flight path, flying height, velocity and trigger are defined. The mission itself runs fully automated, wireless communication allows tracking the actual position of the platform and adapting the flight plan if possible. A semiautomatic mode



or manual mode, e.g. for landing, in case of signal loss or other unexpected problems is also possible. The flight has to be supervised by a qualified pilot, who is able to take over the direct control of the UAV. Flight-attitude data are logged and either transmitted to the ground station in real time or downloaded after the flight. If synchronized with the camera-data the position and angles of the camera can be reconstructed.

3.4 CAMERAS AND SENSORS

Because of limited payload and place, UAV´s are equipped with light-weight consumer cameras or SLR. They deliver images in high quality and resolution, but are often unstable concerning the parameters of inner orientation (IOP). This problem can be solved, while the camera lens is mechanical fixed or a fixed focal length is used. The camera is triggered by the RC and takes images either in predefined intervals (eg. every two seconds) or at predefined locations. The images normally are stored on a SD-card and downloaded after the mission.

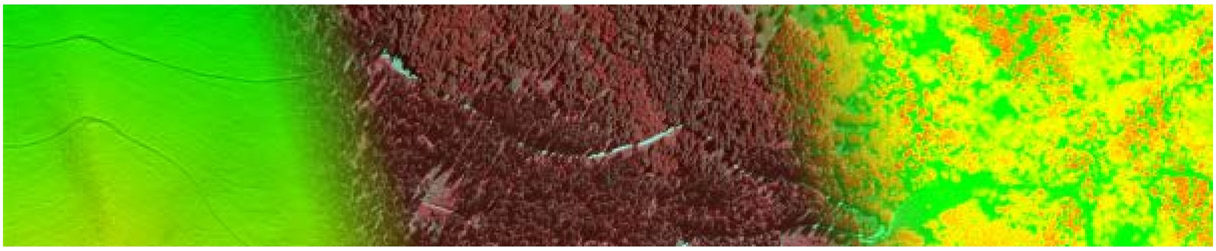
For vegetation-analyses other sensors, e. g. multi- / hyperspectral sensors, NIR, CIR are combined with UAV´s (Zarco-Tejada 2012, Nackaerts 2010, Bendig 2012, Kelcey 2012). Recently small and light-weight models are offered, which are designed especially for application with UAV´s (Tetracam ADC lite 2012).

In the last years also laserscanners (Jaakkola 2010), spectrometers (Jaakkola 2010, NORUT 2012), laser distance rangers and radar sounder (NORUT 2012) are mounted and tested on UAV´s.

3.5 GEOREFERENCING

Georeferencing can be done in several ways:

- Direct georeferencing (defined as direct measurement of camera postition and orientation for each image) can be done with flight attitude data from the GNSS/IMU unit (Pfeifer 2012, Blaha 2011, Eisenbeiß 2009, Geipel 2011, Anai 2012, Chiang 2012,). Real time monitoring systems are also described by several authors, e. g. Akhtman 2011, Rieke 2011, Stempfhuber 2011 and Kim 2012.
- Georeferencing with (additional) use of ground-control-points. In practice, extensive field work could be necessary for installation and accurate measurement of ground control in rough and dense forested terrain.
- Combination of direct georeferencing and ground control. Because of the relatively inaccurate position- and orientation data from the onboard sensors the direct georeferencing method is rarely sufficient without ground control measurements. So, GNSS- and INS data are used for an initial estimation of the exterior orientation parameters (EOP), wich can help to speed up the further image processing significantly.



4 PROCESSING OF UAV-BASED, HIGH RESOLUTION AND SMALL FORMAT IMAGES

There are a few main differences between images from low altitude UAV platform compared to platforms flying at higher altitudes (Turner 2012, Haala 2012, Neitzel 2011, Rieke-Zapp 2010):

- Comparative large rotational and angular variations between images,
- Often not systematic flight lines, due to wind, visibility, terrain conditions,
- large perspective distortions due to relatively large height differences in a scene,
- small footprint of the images, therefore a lot of images have to be collected (and processed) for a good overlap,
- parameters of exterior orientation unknown or not accurate,
- IOP instable because often light-weight and low-cost compact cameras are used (lens retraction mechanisms, autofocus-function)
- high variability in illumination and ground resolution.

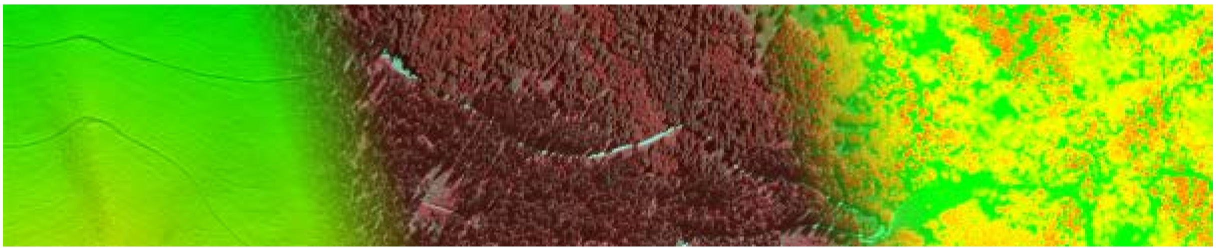
For this reason standard aerotriangulation methods often fails for images acquired with UAV Haala 2012). A variety of open-source and commercial dense stereo matching tools are now available to deal with these challenges. Algorithms (feature detection SIFT, SfM), adopted from computer vision and widely used for close-range photogrammetry or terrestrial photography (Lowe 2004, Bryson 2010, Hauagge 2012) are used. In a highly automated way it is possible, to estimate camera geometry and calculate a 3D.model from a set of overlapping images, invariant to scale, orientation, distortion and illumination changes (Neitzel 2011, Turner 2012). Point clouds as a result from image matching can be further processed in a similar manner than point clouds from airborne or terrestrial laserscanning and are often combined with laserscanning data.

5 HIGH RESOLUTION AERIAL IMAGES IN FORESTRY

5.1 APPLICATIONS

Generally, the first outcome of a image-survey is the photogrammetric evaluation in terms of derivation of digital surface models (DSM, see chapter 1.2) and orthorectified image mosaics. Like traditional aerial imagery (UAV-based) high resolution aerial images provide important basic data for all subsequent geospatial analyses.

For high resolution aerial images all standard image processing, analysis and interpretation methods are used, often in combination with other remote sensing and laserscanning data. A short summary of common methods in forestry applications is provided by Brandtberg



1999b. High resolution images allow forest delineation (Böhm 2010) and vegetation mapping or even tree species classification (Wang 2008, Yu 2006, Gini 2012). Particular attention lies in single-tree-extraction (Culvenor 2002), tree crown detection, tree density, age-classes and further structure parameters, like stem or timber volume. Such parameters can be derived either from object-based image analysis (Steinmann 2011, Böhm 2010, Maltamo 2006, Brandtberg 1999) or from point cloud data as a result of image matching (Bohlin 2012). Stand parameters are a valuable support forest inventory (Wallace 2012, Böhm 2010, Fadaei 2010, Brandtberg 1999a, Chapman 2006) as well as for forest management (Bobbe 2005, Grenzdörffer 2008, Ruppe 2012, Zmarz 2009, Straub 2012). This also includes silvicultural methods and planning and monitoring of harvesting.

The quick setup, the easy transport and operation makes a UAV system to a perfect instrument for monitoring, because of the arbitrary frequency of repeating flights (Häme 2012, Horcher 2004). This is also a great advantage for detection and assessment of damages from wind (Böhm 2010), forest fire (Routledge 2007, Merino 2006, Restas 2006, Smith 2008, McCarthy 2012) or mapping of biotic infections (Böhm 2010).

The application of UAV-borne laser data for forest change detection is documented by Wallace 2012b. Jaakkola 2010 tested laser data from UAV´s for single tree measurements. Berni (2009) mounted a hyperspectral scanner on a UAV for calculating water stress factors (CWSI, canopy conductance). The application of IR-, hyper-, multispectral- or thermal sensors gets already operational for precision farming and agricultural tasks (Universität der Bundeswehr München 2012), e. g. for estimation of leaf area index (Corcoles 2013), calculation of narrow-band indices for detection of water stress in orchards (Zarco-Tejada 2012), mapping states of vegetation and vegetation health (Knoth 2011) and calculation of NDVI and temperature (Bendig 2012, Gini 2012).

5.2 ACHIEVEMENTS AND LIMITATIONS

One of the greatest advantages of this new technique is its high flexibility and the relatively low operational costs. The miniaturisation of the sensors and the increasing reliability of the navigation systems make UAV´s to an instrument for operational applications. In contrast to standard aerial imagery, the better resolution of the data offer possibilities for new developments in image analysis.

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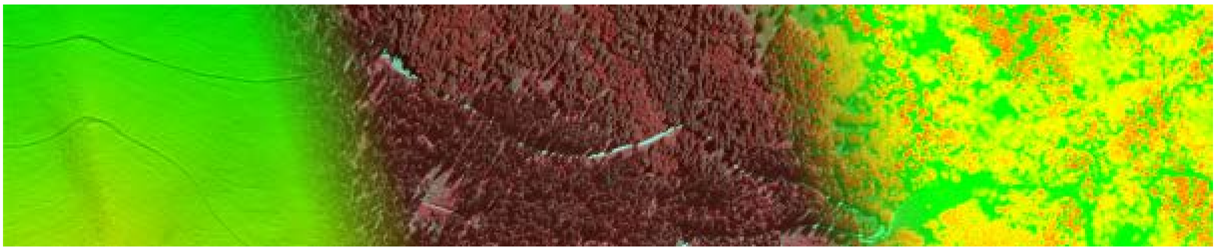

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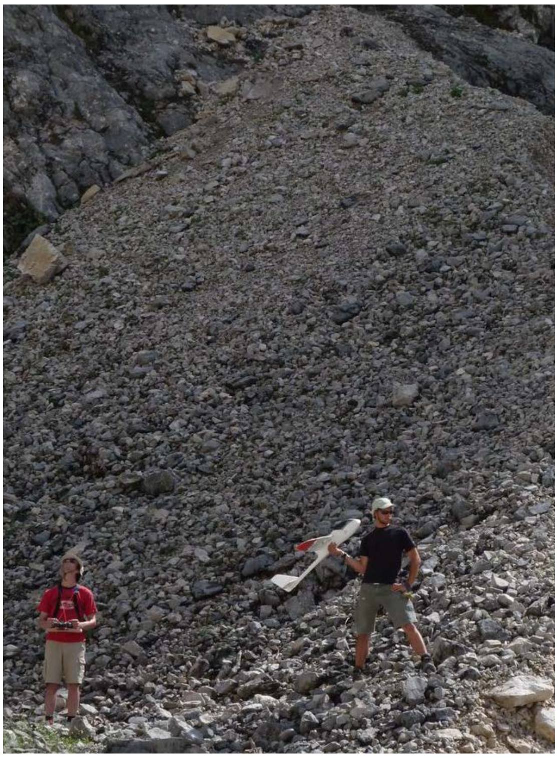
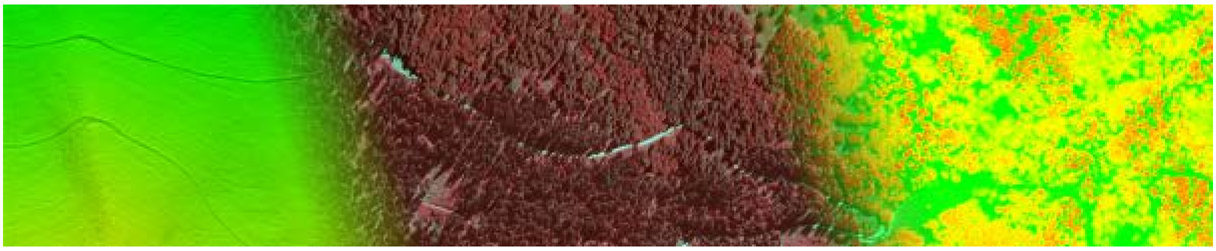


Figure 2: Rough landing sites



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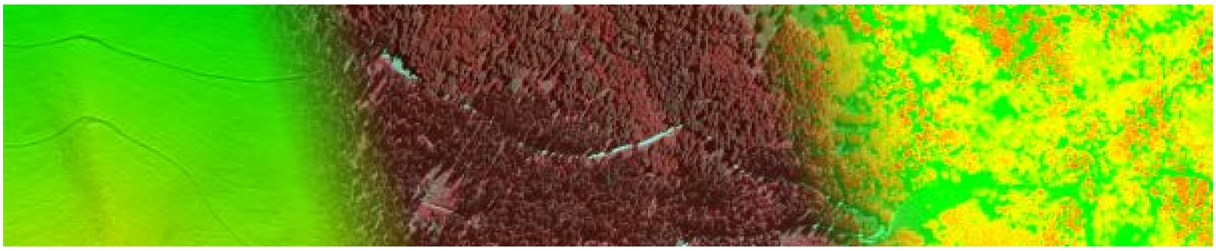

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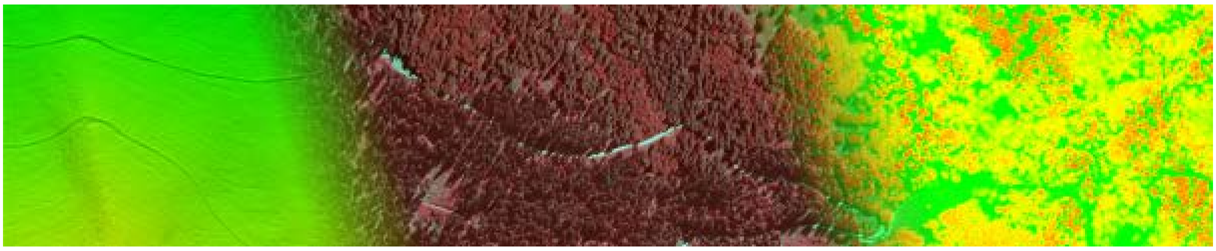

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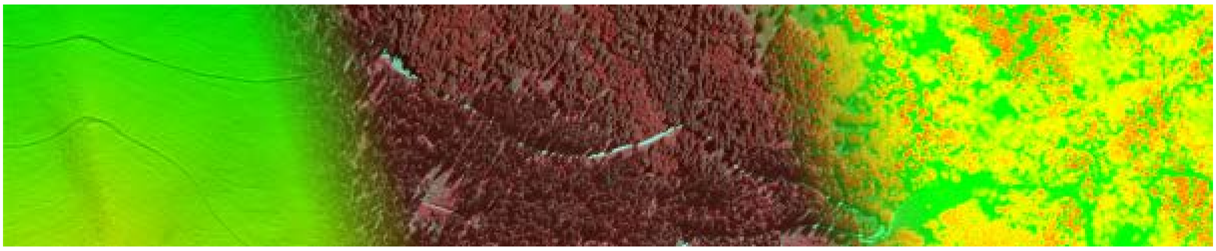

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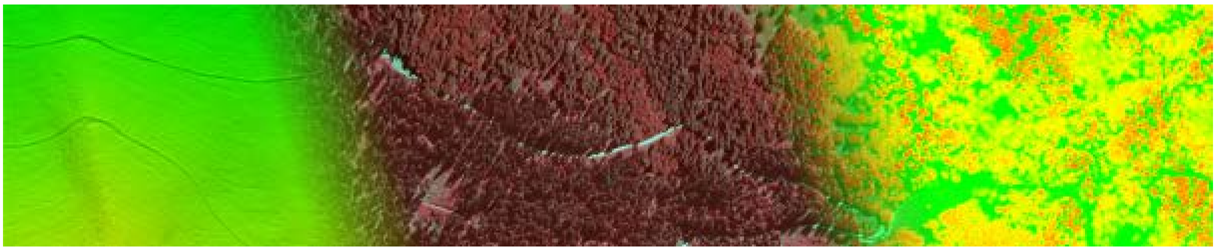

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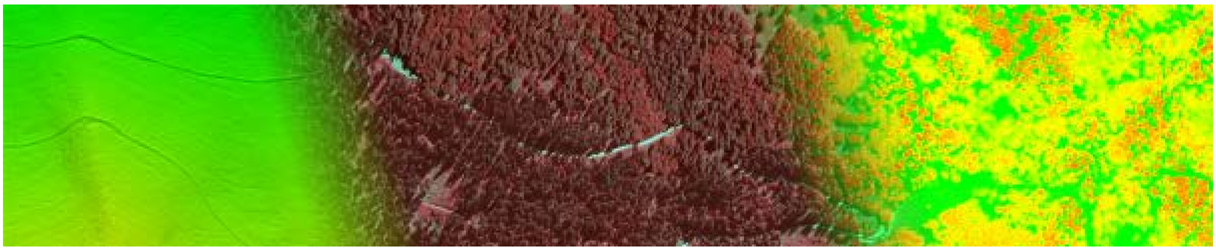

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