Automatic imagery analysis to monitor wood flux in rivers (Rhône River, France)

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Introduction

- Ground imagery can supplement satellite/ aerial imagery and field observations to monitor river dynamics.
- Large datasets can be produced with high temporal resolution but their visual analysis is very time consuming.
- Automation of image processing would allow monitoring river processes using high frequency imagery.
- In-channel wood is known to be valuable for aquatic ecology but it is also a problem for hydraulic structures.
- The Genissiat dam constitutes a great vantage point to assess the wood production in the Rhône River catchment (Moulin and Piégay, 2004) but also to set up a ground camera.
- This site was used to test the automation of the wood production monitoring in a River catchment.
- The wood raft extent in the dam reservoir was used to assess the wood production in the upper catchment.

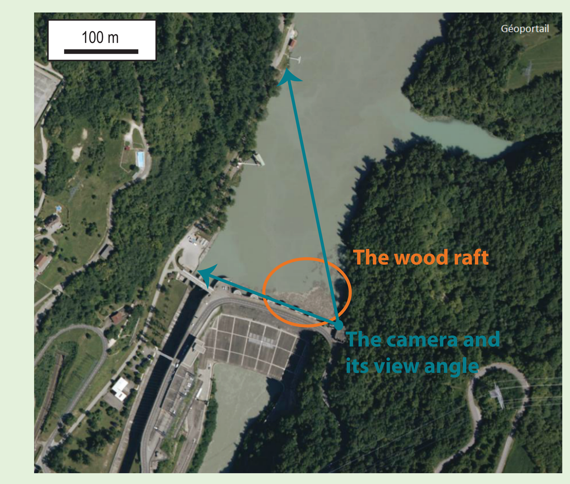
Objectives

- Develop a method to automatically monitor rivers processes, simple and readaptable for numerous processes.
- Identify flow conditions which are critical in terms of wood production in the upper Rhône River catchment.

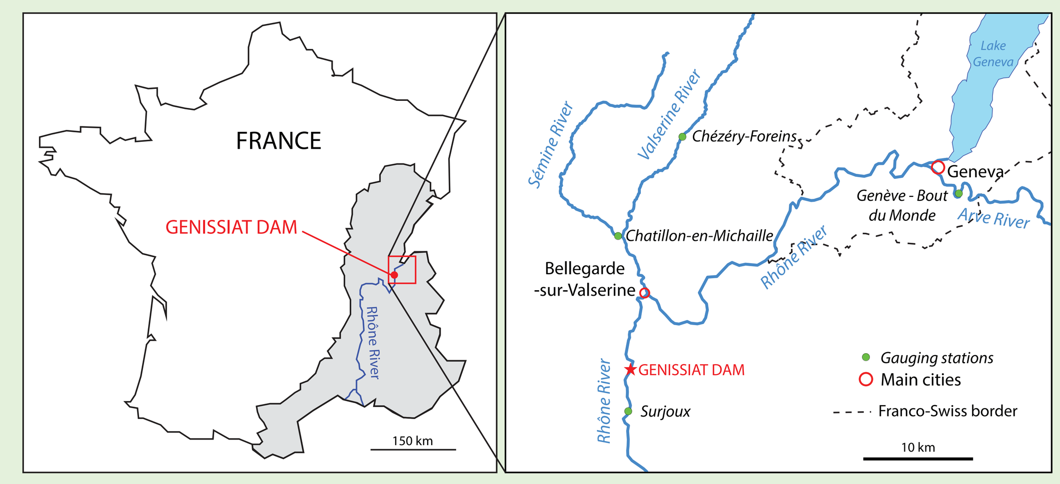
Study site

- The Genissiat hydro-electric dam (Rhône River, France) came into service in 1948.
- Pieces of wood cannot pass through the dam: a raft grows up in the reservoir.
- Mechanical interventions are needed to remove the raft 3-4 times per year.
- Two main tributaries supply wood pieces to Genissiat:
  - the Arve River (catchment area = 1,984km² ; mean annual discharge = 73m³/s)
  - the Valserine River (catchment area = 374km² ; mean annual discharge = 16m³/s)

- Since February 2011
- a 211W Axis camera
- one picture every 10mn
- 640*480 pixels
- bands available: RGB



Upper view of the Genissiat dam and its reservoir.



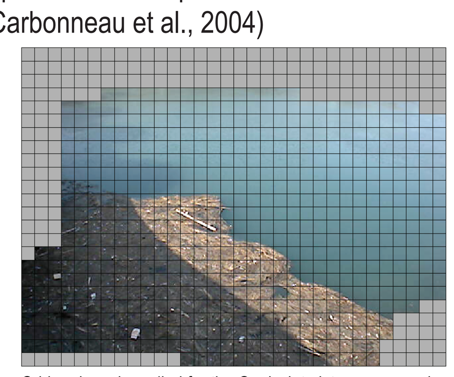
The Rhône River in France and its two main tributaries upstream of Genissiat. Gauging stations used to study the discharges of the three rivers.

Method

The method developped consists in an automatic detection of the wood raft area through time. Simple statistical parameters were extracted from each image in order to classify each pixel of the region of interset into Wood or Water.

A learning sample was used to define the rules to discriminate classes of the pictures. These rules were apply on the whole dataset to draw time series of the wood raft extent.

- Mask application to extract the Region Of Interest (ROI)
- Division of image into a grid of 20*20 pixels squares: 587 sample windows (Carbonneau et al., 2004)



Grid and mask applied for the Genissiat pictures processing

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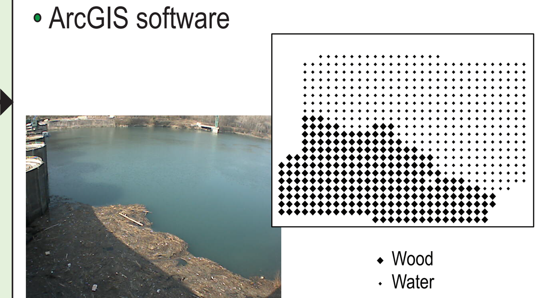
- Calculation of the Hue, Saturation, Intensity (HSI) bands from the RGB bands (Gonzales et al., 2004)
- Extraction of radiometric and textural parameters: > in each square of the ROI > in the RGB and HSI bands
  - Mean
  - Median
  - Variance
  - Mode
  - Standard deviation
  - Range
  - Interquartile range
  - Textural inertia (Conners et al., 1984)
  - Difference between each RGB band
- R software

- In a validation sample: 92 images chosen randomly or for their visual properties →
- In the whole dataset →

- Manual classification of each square of the ROI (Wood/ Water)
- ArcGIS software



One example of manual classification: image taken the 2011-02-02 at 13:20

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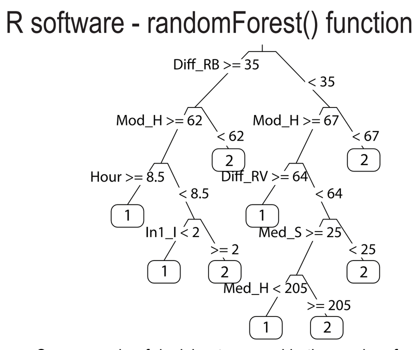
- 20,000 squares chosen randomly
- Random forest (Hastie et al., 2009)
- R software - randomForest() function



One example of decision tree used in the random forest

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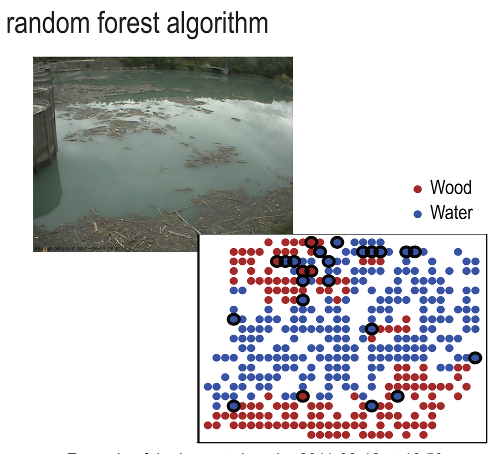
- Prediction of the classes thanks to this random forest algorithm



Example of the image taken the 2011-08-12 at 16:50. Errors during the prediction are circled. White squares are out of the ROI or used in the learning sample.

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- Orthorectification of the images
- Fudaa - LSPIV software (IRSTEA)

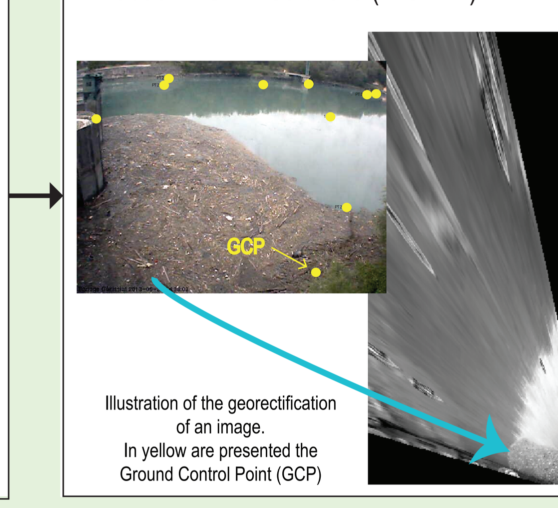
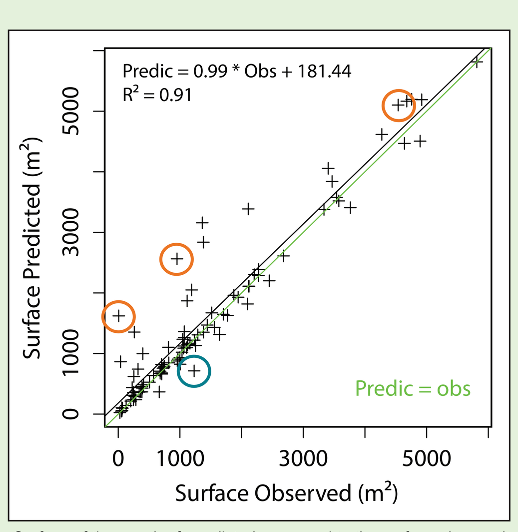


Illustration of the georectification of an image. In yellow are presented the Ground Control Point (GCP)

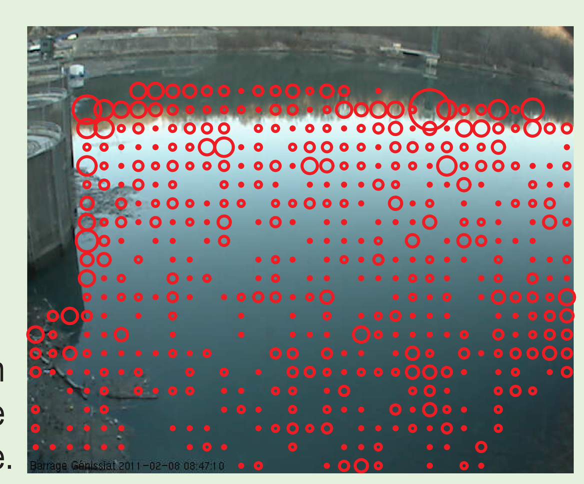
Results



Surface of the wood raft predicted compared to the surface observed in the pictures of the validation sample

The regression line between predicted and observed wood surfaces reveals an accurate predictive model (slope=0.99; R²=0,91). The largest discrepancies are associated with pictures showing bad limunosity or severe cloud reflection.

Most of the bad classifications are located in the backgroud of the image: where the squares have the most important surface. Some elements of the right bank produce reflection which drive to bad classification.

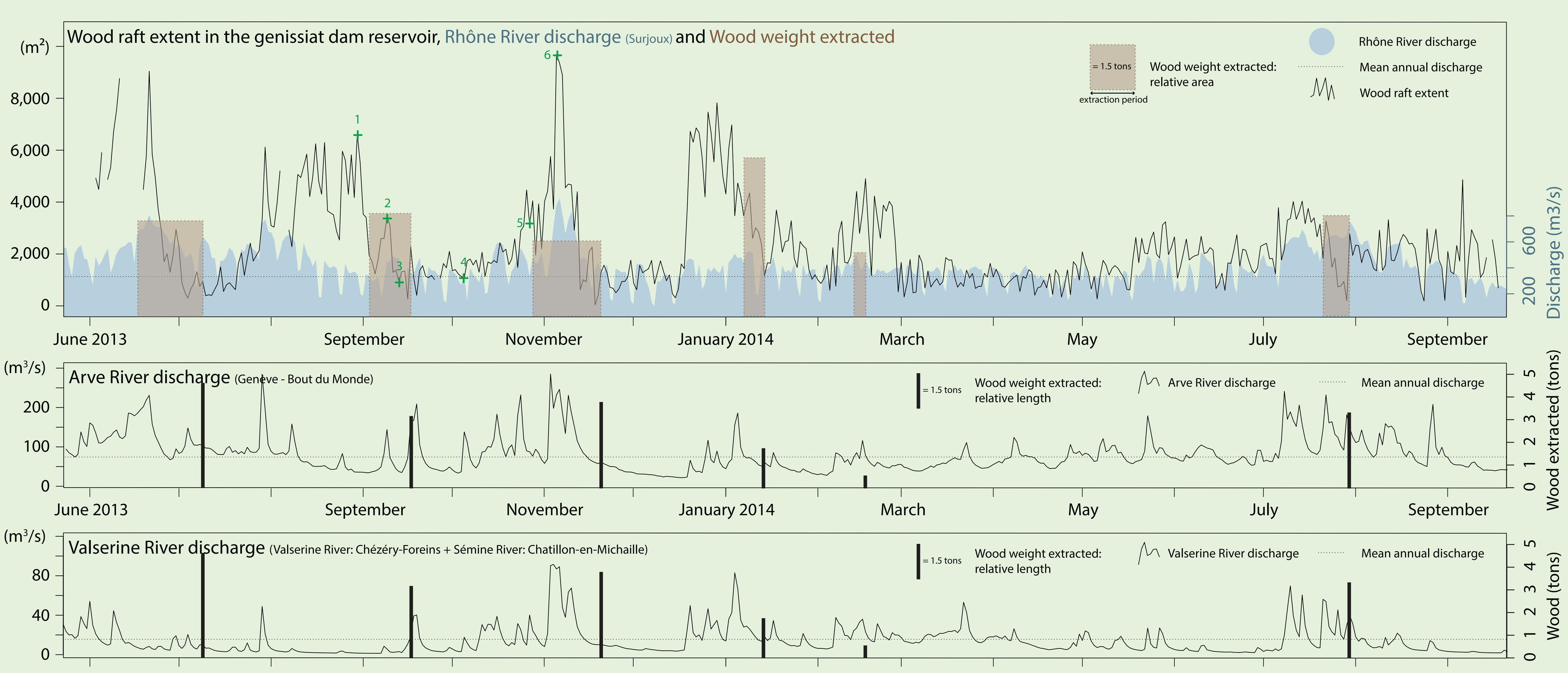


Number of errors which occurs during the class prediction in the squares of the validation sample: circles are proportional to the number of bad classification.

Hereunder, the time series of wood surfaces obtained from proccessing 461 pictures between June 2013 and September 2014 reveal the co-occurence of large wood surfaces and high peak discharges in the Rhone River. They also show the decreasing raft extent when mechanical extraction is performed.

In November and December 2014, floods of the Valserine River seem to be more efficient than those of the Arve River, in terms of wood production. Floods occuring only on the Arve River don't seem to produce such quantities of wood (May and August 2014).

Six images are pointed on the graphic to illustrate the aspect of the wood raft through time.

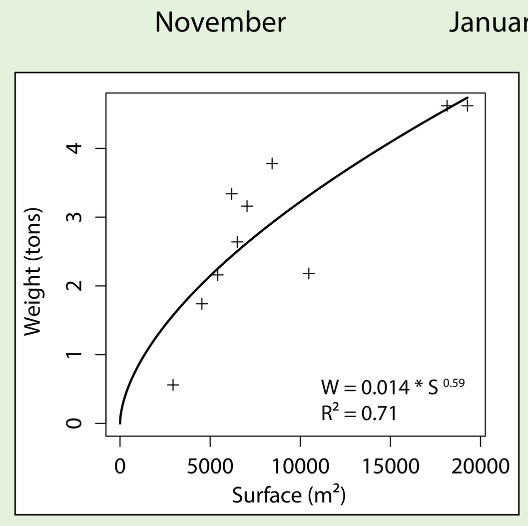


From wood raft area to wood volume:

During each extraction operation, quantities of wood extracted were weighted.

10 operations were recorded on pictures: the surface observed the day before each operation was compared to the weight measured.

We chose to work with a non-linear function that passes through the origin for the physical signification.



Weight of the wood extracted compared to the surface observed the day before extraction

Conclusion and Perspectives

- Monitoring the evolution of a wood raft extent through ground imagery is confirmed and efficient.
- Assessment of the wood raft extent could be more accurate if the water level changes were taken into account.
- The method has to be tested on other datasets or objects, for example located under the water level surface.
- The Valserine watershed, despite a lower discharge, seems to be more prone to wood supply than the Arve watershed, in the upper Rhône River at Genissiat.

References

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