

# TRENT2D WG: A SMART, WEB-BASED MODELLING SOLUTION TO ASSESS DEBRIS-FLOW HAZARD IN MOUNTAIN REGIONS

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## KEY POINTS

- TRENT2D WG is a smart system conceived to encourage the diffusion of advanced modelling in debris-flow hazard assessment, taking advantage from SaaS approach and WebGIS technology.
- TRENT2D WG is based on the state-of-the-art model TRENT2D, which was converted into a service, exposed on a cloud server, supplied with an intuitive GUI and made accessible through the Web.
- TRENT2D WG can be used profitably to assess debris-flow hazard, applying in succession the TRENT2D model and the GIS-based BUWAL-type hazard-mapping procedure integrated into the web system.

## 1 INTRODUCTION

Mountain regions are exposed naturally to extreme flood events that involve large amounts of sediments. These events are known as geomorphic flows and include for instance debris flows and hyperconcentrated flows.

In the last decade, several mathematical and numerical 2D models have been developed to describe these phenomena with increasing complexity and reliability (see *Iverson & Ouyang*, 2015 for an overview). Advanced modelling can represent an important support in hazard management, facilitating the diffusion of effective protection and mitigation strategies. However, practitioners and stakeholders often disregard state-of-the-art models, preferring simpler, but rougher, models and methods to assess hazard. For this reason, some effort seems to be necessary to push the diffusion of the most advanced models, encouraging the application of “appropriated best practice and best available technologies” in flood-risk assessment and management, as recommended by the UE Flood Directive (2007/60/CE).

In this work a new solution is proposed for TRENT2D (*Armanini et al.*, 2009; *Rosatti & Begnudelli*, 2013), a state-of-the-art model that simulates debris flows and hyperconcentrated flows. This solution, called TRENT2D WG, aims to overcome some of the typical drawbacks of advanced modelling and to bring research closer to professional needs. Moreover, such a system can be used profitably also in hazard assessment and mapping.

## 2 TRENT2D WG: A WEB-BASED SOLUTION FOR DEBRIS-FLOW MODELLING

TRENT2D WG is a smart web infrastructure designed for the TRENT2D model. It was developed starting from two basic ingredients: the Software as a Service (SaaS) approach, which is a particular kind of software-delivering model, and the Web-based GIS technology, which offers GIS functionalities through the Web. Thanks to these components, TRENT2D WG allows TRENT2D to be applied in a complete and user-friendly environment, which offers several advantages for the user and which can be accessed through the World Wide Web by any device.

### 2.1 The TRENT2D model

TRENT2D (*Transport in Rapidly Evolutive, Natural Torrent*) is an advanced 2D model which simulates debris flows and hyperconcentrated flows over a mobile bed. It is based on a two-phase description of the solid-liquid mixture, without velocity lag between the phases. The mobile-bed approach and the two-phase description allow to represent properly erosion and deposition processes, which are typical processes of geomorphic flows. Erosion and deposition cause significant variations of bed elevation, which are fully-coupled with the mixture dynamics.

TRENT2D governing equations are characterised by high non-linearity and show non-conservative terms.

Therefore, a sophisticated numerical model is considered to solve them properly. In particular, a finite-volume method was chosen and applied over a Cartesian mesh, with Godunov-type fluxes and second order accuracy in space and time. For further details about mathematical and numerical aspects, refer to *Armanini et al.* (2009) or *Rosatti & Begnudelli* (2013).

However, complexity and high-nonlinearity lead to large computational burdens, which should be supported by suitable high-performing hardware that could not be within of reach of practitioners.

Moreover, TRENT2D requires geographic data as input (i.e. at least a DTM of the study area) and produces several geographically referenced data as output. The management of this data volume can be supported profitably by GIS systems. However, TRENT2D does not support GIS functionalities itself. Therefore, the user is obliged to organise and process geodata by means of stand-alone GIS applications, with consequent work fragmentation.

## 2.2 SaaS approach and WebGIS technology

For the purpose of solving such drawbacks connected to the use of TRENT2D, the TRENT2D WG system was developed joining advantages offered by the SaaS approach and by WebGIS technology.

SaaS represents a particular software-delivering model that moves away from standalone-software logic. According to SaaS, software is provided as a service and hosted by a suitable cloud server. Service can be accessed through a GUI (Graphic User Interface), by means of a common Internet browser, almost independently of the accessing device properties. In this way, software is available through the World Wide Web, from any Internet-connected device. Moreover, computational burden is moved to a suitably equipped server, relieving hardware requirements for the user. For these reasons, a huge variety of web applications have been developed according to SaaS, suggesting to exploit this promising strategy also in the modelling field.

In the last years, the SaaS model has represented the basis also for several Web-based GIS applications. A WebGIS is an application that allows to display, organise and process geographic data through the web (*Plewe, 1997*), by means of a suitable GUI. In this way, GIS functionalities are made available through the Web, employing interoperable standards of the Open Geospatial Consortium (OGC ©). WebGIS applications have already been used in hazard management, especially as decision-supporting tools or historic databases. However, their huge potential (*De Amicis et al., 2009*) still has to be explored in depth for modelling purposes.

## 2.3 TRENT2D WG

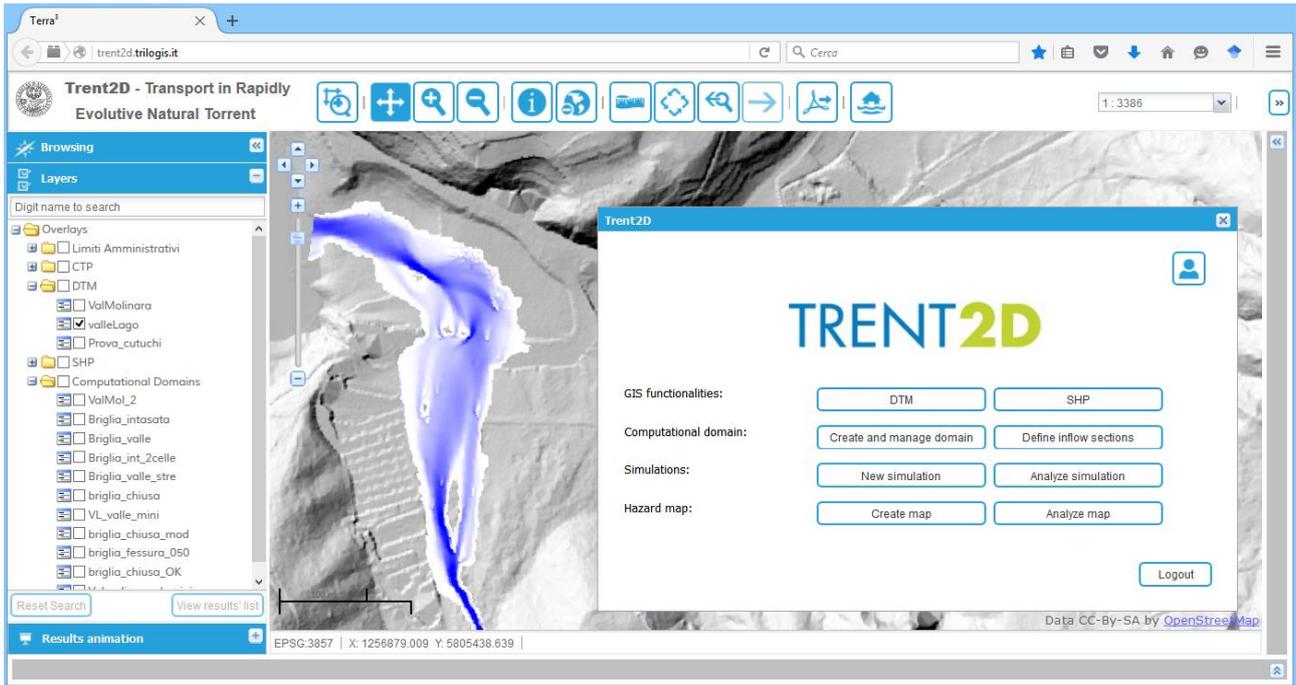
TRENT2D WG (Figure 1) is a smart modelling solution, which aims to enhance and simplify the use of the TRENT2D model, complying with the SaaS approach and taking advantage of WebGIS technology.

TRENT2D WG was developed converting the TRENT2D model into a service and exposing it on a cloud server. The infrastructure was equipped with a WebGIS client, hosted on the same cloud server and suitably customised. Moreover, thanks to its characteristic flexibility, TRENT2D WG was enriched with several ancillary services, i.e. functionalities tailored mainly to process TRENT2D input and output data and to analyse model results carefully.

The infrastructure can be accessed by the most common Internet browsers, through an intuitive GUI that allows users to invoke all the available services. In this way, the model can be applied easily and in a complete working environment, which guides the user to prepare model input data and to process model results easily. Moreover, it allows to manage, display and overlay geodata efficiently and without fragmentation, i.e. taking advantage of a single infrastructure instead of multiple standalone software.

Furthermore, users benefit of the server capacity, which takes on the whole of computational cost and all data-storage burdens. Since the infrastructure is supported by a high-performing server, model computational time is significantly reduced and expensive investment in user local hardware is no more necessary. In addition, hardware damaging can be excluded and data integrity is safeguarded.

System administration and maintenance are centralised, facilitating debugging and upgrading tasks and making updates available at the same time for all the users.



**Figure 1.** Working environment of TRENT2D WG.

A beta version of TRENT2D WG is available at [trent2d.trilogis.it](http://trent2d.trilogis.it), upon registration.

Such an integrated modelling system can be exploited profitably for different purposes, as for instance to back-analyse real past events, to evaluate the impact of multiple hazard scenarios or to estimate the hydraulic efficiency of some designed protection and mitigation structures. Also hazard mapping can take advantage from the system TRENT2D WG, as described in the following Section.

### 3 MAPPING DEBRIS-FLOW HAZARD WITH TRENT2D WG

Hazard maps represent essential tools in supporting hazard mitigation strategies and in planning safe urban expansion. Therefore, particular attention should be paid to the reliability of the employed hazard-mapping procedure, which could be enhanced significantly if advanced and physically-based models are used in hazard assessment.

The TRENT2D model has already been for hazard mapping purposes, with interesting and trustworthy results in several engineering applications (see for instance *Rosatti et al.*, 2015). Consequently, it seemed to be convenient to enrich TRENT2D WG with a service devoted expressly to hazard mapping, taking advantage of the SaaS approach. This service was called Hazard Mapper and was implemented complying with BUWAL directives (*Heinimann et al.*, 1998), according to a probabilistic approach.

The Hazard Mapper classifies local debris-flow hazard levels through the BUWAL matrix, where hazard is described as a stepwise function of the probability of occurrence and of the intensity of three significant scenarios. Each scenario is intended to be representative of a particular value of the occurrence probability and its local intensity is classified thoroughly by means of threshold criteria, generally stated by local authorities. Reliable hazard scenarios can be simulated profitably by means of advanced models such as TRENT2D. Therefore, the use of TRENT2D WG seems to be particularly appropriate, since it allows to model scenarios properly and to analyse time and space evolution of the phenomena by means of a user-friendly environment.

However, once scenarios have been defined and modelled, they need to be classified in terms of occurrence probability and intensity. Classification could become a long and laborious task, since a large number of maps must be considered and several sequential criteria must be applied. For this reason, TRENT2D WG was equipped with the Hazard Mapper, a service that applies classification criteria

automatically, overlaying multiple maps autonomously. The Hazard Mapper works in the same environment where scenarios have been modelled and where model results are available straightforwardly. Moreover, hazard maps produced by the BUWAL-type procedure can be displayed and analysed effectively with the TRENT2D WG GUI.

#### 4 CONCLUSIONS

In this work, a new web modelling system was presented. The system, called TRENT2D WG, was intended to overcome some drawbacks of using the TRENT2D model for both research and engineering applications. Joining the SaaS software-delivering model and WebGIS technology, a smart and user-friendly infrastructure was developed. TRENT2D WG offers several services that can be accessed through the Web, by means of a single login by any Internet-connected device. In this way, it is possible to simulate debris flows and hyperconcentrated flows reliably, to pre- and post-process model input and output data easily, to analyse model results thoroughly and to map debris-flow hazard straightforwardly.

Thanks to its characteristic flexibility, the system could support also other functionalities and other models, as for instance rainfall-runoff models or snow-avalanche models.

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