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Short Communication

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The Global Hydrogeological Risk in Italy, a Threat that is too often Underestimated

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Abstract

Italy is a country that has always been "battered" by hydrogeological breakdowns, landslides, floods; the highly critical areas represent 9.8% of the national surface and cover 89% of the municipalities, on which there are 6,250 schools and 550 hospitals, as documented by an interesting article on "Data Journalism" published by La Stampa's medialab (Italian newspaper). About 6 million people in Italy are threatened by landslides and floods. The following work is intended to be a contribution to the dissemination and circulation of a correct geological culture, in a country where there is no adequate training in Geological Sciences in schools. Although there is a very efficient public civil protection service prepared to deal with emergencies following disasters, it is still too little, what governments and institutions spend on disaster prevention that must necessarily pass for proper training and information of citizens. The present work also wants to propose a concrete solution to the problem, with the presentation of a simple but innovative system to mitigate the negative effects of the large waterproof surfaces present in our cities. The HCS Hydro Control System provides for the creation of "domestic" microbacines, for the storage and reuse of rainwater coming from waterproofed surfaces. It would be very interesting to put the HSC method into practice just as an experiment. Given the vastness and complexity of the survey, mainly cartographic tools such as, thematic maps (Geological map of Italy, maps of natural hazards, historical meteorological bulletins and data published in journalistic articles, ISPRA monitoring data) were used. The excessive vulnerability of the Italian territory must be sought in a series of concomitant factors, starting from the particular geological structure. The relatively recent formation, from the geological point of view of Italy and the islands except Sardinia, dates back to the Middle-upper Miocene (about 8 million years ago), a very short geological period, unlike the rest of the European continent. We must also consider human activities that can only increase the vulnerability of the territory: rapidly urbanized areas in risk areas, increase of impermeable surfaces, and reduction of water runoff lines. There are also some examples of disasters, related to hydrogeological instability, which hit Italy: the Vajont landslide in 1963 and the spread of beta-hexachloro-cyclohexane pollution in the lands of the Sacco river valley in southern Lazio. The analysis of the hydrogeological risk in Genoa, which has always been affected by alluvial events, often destructive, linked to the particular geomorphological conformation of the territory, is an excellent starting point to verify the effectiveness of an important hydraulic work, the drain of the Fereggiano torrent in Genoa, for the derivation, in the case of full of well110 m^3/s of water.

Keywords: Landslide; Hydrogeological risk; Earthquake; Groundwater

The Vulnerability of Italian Territory

According to a recent ISPRA report (2018), on the risk and relative indicators of hydrogeological instability in Italy, a rather worrying picture emerges. The data reported in the report were provided by the eight district basin authorities, bodies responsible for the management and monitoring of phenomena related to the prevention of hydrogeological instability. In addition to updating data on populations, businesses and cultural heritage at risk, the recent report contains two new indicators: families and buildings (Figure 1).

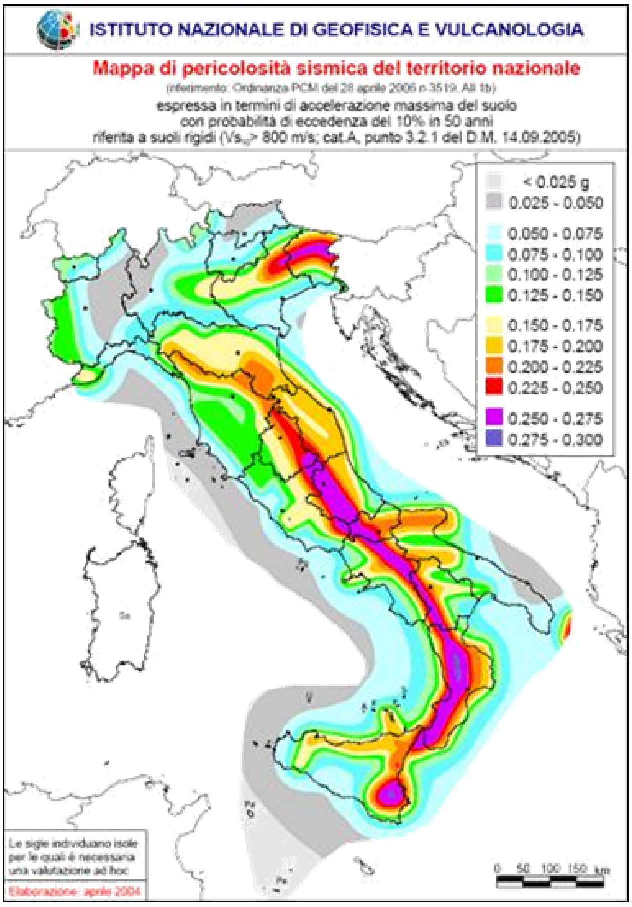

Figure 1: From the seismic risk map, INGV 2004, it emerges that landslides and earthquake hazard of the territory are directly connected. Comparing the map of the seismic danger with that following the landslide index, the case of Sardinia is very evident, whose geological history and therefore the seismic-tectonic nature of the island are very different from the situation of the rest of Italy.

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The methodology adopted for the production of the indicators respond to the criteria of transparency and replicability and return data on a citizen, regional, provincial, municipal and aggregate basis for geographical macro-areas and for the distribution of structural funds. Key figures for the 2018 edition: 7,275 municipalities (91% of the total) are at risk due to landslides and/or floods; 16,6% of the national territory is classified as more dangerous; 1.28 million inhabitants are at risk of landslides and over 6 million inhabitants at risk of floods. According to our point of view, which coincides with that of many scholars, the alluvial and landslide phenomena are closely intertwined and represent some of the main triggers of important events (Figure 2).

Below is a map of the Italian territory where you can see the index of landslide. From the map on ISPRA (2017) we can deduce at least three very interesting elements:

The maximum margin index (>30%) concerns the mountainous and hilly areas that mainly coincide with the Apennine ridge. Less is the impact on the Alps and on the Calabro-Peloritano arch.

Sardinia represents an area with a low degree of landslide. (We do not consider the different areas mainly flat as the Po Valley and most of Puglia, in these areas the average slope is very low).

Areas with the highest degree of landslide often coincide with areas with high seismic risk.

Figure 2: Data medialab “La Stampa”- Data journalism.

The interesting article published by "La Stampa" previously mentioned, effectively shows the correlation between landslides and floods, in an animated graphic that manages to communicate the problem in an essential and complete way (Figure 3).

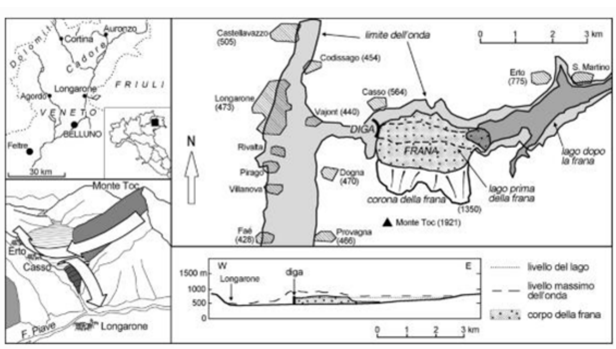

Figure 3: General outline of the Vajont landslide (1963) da Revue Culturelle Trimestrielle Bilingue de l'Association Notre Italie.

The causes that trigger the landslide-alluvial phenomenon are many, starting from the geomorphology of the areas, considering that over 75% of the Italian territory is mountainous or hilly, the increase of the surfaces waterproofed due to a wild cementing, population density that in certain geographical areas are high, the lithological nature of the territory consists mainly of Miyfenic Flyshoidi Deposits, very fragile from the point of view of stability [1].

To all this we add a factor that could be defined as "global", the increase in average temperatures of the atmosphere with a consequent increase in the phenomena of violent rains (Figure 4).

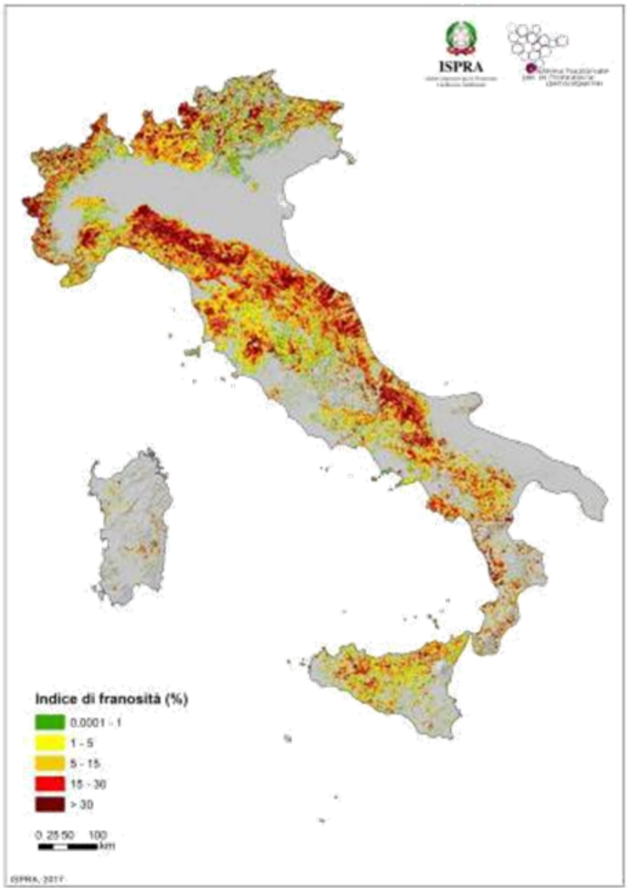

Figure 4: ISPRA landslide risk map 2017.

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Figure 5: Photo published in the newspaper Ciociaria Today on July 19, 2018.

The analysis clearly shows how the Italian territory has changed, which in the last fifty years has reduced the area by 4.1% with an ever increasing annual average of the degree of erosion. Land consumption has reached a speed of over $8m^2$/second over the past five years.

The progressive reduction of the natural infiltration of meteoric water in the ground due to the increase of waterproofing surfaces due to structures and infrastructures, has led to a notable increase in the flow of running water with increasing erosion potential over time (Figure 5).

The Concept of Hydrogeological Risk

When we talk about "hydrogeological risk" related to a given territory, we usually refer to the the possibility that a natural phenomenon or induced by human activities can cause harmful effects on the population, housing and production facilities and infrastructure, within a particular area, over a given period of time. From an analytical point of view, risk is the product of concomitant factors: danger, vulnerability and exposure. Often one is led to confuse the concept of risk, with the perception of danger. In fact, a given cause triggers a destructive data the event will produce very different effects depending on the geographical area in which it will occur (Figure 6). We often learn that a magnitude 6 earthquake in Japan causes no more than ten deaths, in Italy an earthquake with the same intensity usually causes a quantity three or four times higher. If we want to quantify the risk, we can refer to a mathematical relationship:

$R = P \times V \times E$

Where:

R=risk;

V=vulnerability;

E=exposure;

Figure 6: Ing. Simone. Venturini * The project of the drain of the river Fereggiano in Genova" (basin of the Bisagno torrent) Technitaly Nov. 2017.

Dangerousness is a factor linked to the probability of an event occurring, of certain intensity in a certain period of time in a specific geographical area. The vulnerability is the propensity to suffer from subjects (people, buildings, economic activities) damages deriving from the calamitous event. The exposure or value exhibited constitutes the number of people, buildings, businesses and infrastructures potentially threatened by the destructive event. Il rischio idrogeologico "globale" in cifre.

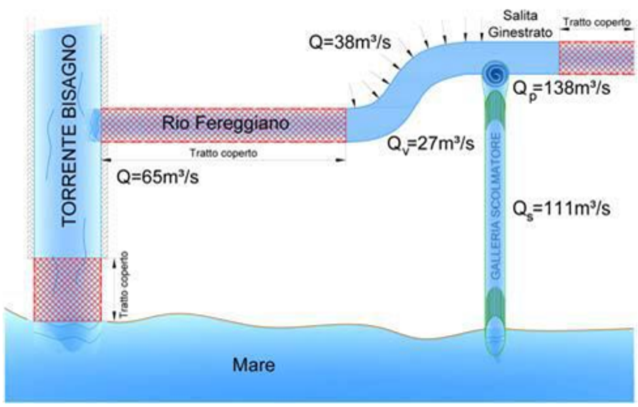

Figure 7: Distribution of the flow rates to be obtained with the works, assuming reference to the flow rates estimated on the occasion of the event November 4th 2011 (Perizia Bellini / Tubino).

Currently, throughout Italy, 17,255 km^2 of land are at high risk of landslide, while 12,263 km^2 are at high risk of flooding. A total of 5,798,799 people were involved, with 3302 deaths due to landslide from 1963 to 2012 and 692 deaths due to flooding (IRPI CNR). The public utility buildings, subject to global risk, are 6250 schools and 550 hospitals, a huge threat. A striking example in his true drama was the Vajont disaster in 1963, when on October 9, at 22.39 local time, a huge landslide of 270 million cubic meters broke off from the side of Mount Toc, on the border between Veneto and Friuli, overwhelming the artificial dam downstream. A giant wave, similar to a tsunami, which killed about 2,000 people (Figure 7). A dramatically evident example of underestimation of Italian hydrogeological risk. Regional governments have estimated a need for 40 billion euros for land security, but the central government, in the latest stability law, has allocated only 180 million for the next three years. To further aggravate the picture is the

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consumption of soil, increased by 156% from 1956 to today, compared to an increase in the population of 24%. Every five months an area equal to the City of Naples is cemented, a fact that highlights the responsibilities of man, for these disasters, which only in the last fifty years have caused the death of over 4000 people?

The Chemical Risk Related to Hydrogeological Risk

Groundwater circulation is often the cause of the spread of polluting chemicals in shallow and deep aquifers, with an increased risk of chemical contamination of groundwater due to the presence of abusive or improperly designed water wells. In this regard, consider the striking case of the Valle del Fiume Sacco in the province of Frosinone (central Italy).

"It was July 19, 2005 when a farmer found the first dead cows near the creek, they were 25. All were mobilized by the police (carabinieri, gurdia forest and provincial police intervened on the spot) to politics. There was talk of "an anomalous tragedy" and "an episode of poisoning. There have been massacres with damages resulting from an economy, historically farm. Only a few months before, a little further north, the case of beta-hexachloro-cyclohexane, a dangerous chemical agent, in the milk of a farm in Gavignano (Rome).

The dangerous β - HcH pollution of the Sacco River has also affected the flood areas of the river as a result of flooding the river, which invade the agricultural areas of the territory and contaminating groundwater. The same wells were subsequently used to irrigate the land housing agricultural crops. The presence of water wells in the area has accelerated the process of deep penetration of water contaminated by chemical agents (Figure 8).

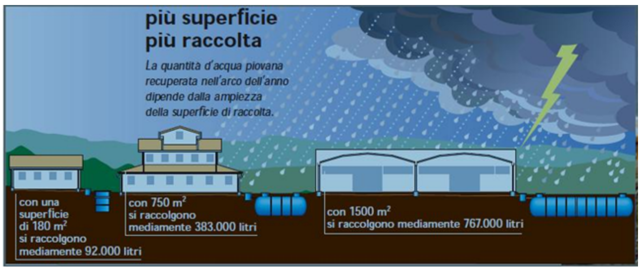

Figure 8: Water storage and recycling system.

The vulnerability of groundwater should be safeguarded with efficient monitoring systems. In this area it is necessary to intervene with a radical reclamation of the area, on the entire water / soil system.

A Practical Approach to Risk Reduction: The HCS Method (Hydro Control Sistem)

Italy has a high population density, with 200 inhabitants / Km^2 occupies the 42^{nd} position worldwide. In some cities the density rises considerably, this aspect, inserted in a delicate geological context, has a significant impact on the hydrogeological equilibrium. If one examines the particular case of the city of Genoa, which has always been hit by sudden and destructive floods, it is possible to demonstrate how a solution is the gradual removal of the risk factor on which it is possible to act concretely. The geomorphological framework in which the city of Genoa is inserted is very complex, with valleys that descend towards the sea from the Ligurian-Po Valley watershed. The mountain ranges are between 400 and 1200 meters s.l.m. The territory is classified as "coastal mountain". The highest point of the municipal territory is Mount Reixa at 1183 m altitude; the high slope and the low permeability of the land is a strong element of hydrogeological risk for Genoa.

The drain, built to lighten a portion of the floods of the Torrente Fareggiano. 3.5 km long and with a diameter of 5 meters, it represents a great work of hydraulic engineering for the safety of the Ligurian capital, in case of full flow of the stream it is possible to derive up to 110 m^3/s of water, transporting them directly to the Tirrenian sea.

With the HSC system we can achieve a similar result, but with a greater balance in the hydrogeological balance.

If we consider the relationship, for a specific area:

$P=E \times R \times I$

Where:

P=Precipitation; E=Evapotranspiration; R=Surface runoff; I=Infiltration;

Runoff is the term that determines the increase in the hydrogeological risk factor, especially in areas with a high average slope. The kinetic energy of run-off water determines the rapid erosion of the slopes, the slope at the foot of slopes and the rapid transport of debris even on the roads. Wastewater disposal systems, such as drains and sewers, are often ineffective due to the rapid clogging of debris during periods of heavy rainfall.

Waterproofed surfaces: roads, roofs, square; have subtracted a relevant rate of capacity to the ground, even if modest, to absorb by infiltration water into the ground until it reaches the stratum level. Under such hydrogeological conditions, intense precipitation rapidly transforms the maze of roads into a truly menacing hydrographic network. The main stream (River, Torrent or even road) is quickly fed by turbid currents with considerable debris (branches, debris of various kinds and solid urban waste). The evolution of the process is tragically known.

The reduction of the R factor is therefore strategic for the mitigation of landslide and flood risks in certain areas.

The sewers act directly on the flow rates of the natural and artificial watercourses, carrying, in the case of Genoa, huge masses of water directly at sea. The weak point of this system is related to the weather conditions of the sea. In the event of high tides or contrary currents or contrary winds, considerable limitations may occur to their action creating a real dangerous "natural plug" which also completely obstructs the flow of water, creating a sort of upward regurgitation.

The drainage systems are hydraulic works that act as a by-pass to keep the level of watercourses below the safety threshold. Their action, even if effective, does not reduce the problem of absolute flow due to R (surface runoff).

With the HSC system it is possible to reduce the R factor by temporary storage of the water coming from the waterproofed surfaces: roofs of buildings, squares, roads, etc.

The project idea is linked to the concept of Circular Economy: the water coming from the waterproofed surfaces must be collected and reused for domestic and/or irrigation purposes. The idea of creating a "widespread" reservoir in the territory will lead to a lowering of the hydrogeological risk threshold due to the reduction of the R factor linked to surface runoff of rainwater (Table 1).

	Hydrological data Bisagno basin	Dato		S.I.		Note
a	Surface of the Bisagno basin	95	Km^2	9,5E+09	m^2	ISPRA data
b	Rainfall	400	mm	4,0E-01	m	Pluviometric bulletin 15 nov 2015
c	Infiltration and absorption	20	mm	2,0E-02	m	deduced from the hydrogeological characteristics of the land
d	Evapotraspiration	30	mm	3,0E-02	m	deduced from the hydrogeological characteristics of the land
e	Runoff	350	mm	3,5E-02	m	R= P - I - E from hydrogeological balance
f	Waterproofing coefficient	0,7	%			based on average population density
g	Medium flow Bisagno torrent	1323	m^3/s	1,30E+03	m^3/s	Cartogis Genova data
	Hydrometric calculation					
a	Total waterproofed surface	Simp=a x f		6,7E+09	m^2	
b	Total volume of runoff water	VR=e X Simp		2,3E+09	m^3	
c	Runoff flow rate	QR=VR /s		2,7E+04	m^3/s	Calculated on the day of November 15, 2018
d	Runoff flow net of Bisagno flow	QR=QR -g		2,6E+04	m^3/s	Cartogis Genova data
e	Storage coefficient	0,05		5,0E+02	m^3/m^2	Arbitrarily set
f	Storage volume HSC	Vstox=Vr x Cstox		1,2E+08	m^3	Overall volume of diffuse microinvases

Table 1: Hydrometric calculations.

It would be enough to insert in the building regulations, a specific clause that provides for the realization, by those who request a permit to build or to carry out extraordinary maintenance and or restructuring of small rainwater storage tanks. From time to time underground tanks will be installed, with a volume proportional to the waterproofed surfaces of the building. The microinvases, whose storage volume will be proportional to the waterproofed surface of the roof of the building or the access road or the parking lot, will have the temporary storage function of the water replenishing, in fact, the factor I (water infiltration in the ground) that is fundamental in the global hydrogeological budget.

A sort of multiple, "tiny drainage", spread over the entire territory, which will determine the reduction of surface runoff. For a city like Genoa that has a density of about 2040 inhabitants/Km^2, considering a resident population of about 580 thousand inhabitants, distributed over a surface of the metropolitan city of over 240 Km^2, it would be a very opportune choice that of the widespread microinvases. The data from the weather reports show us the rainiest period in Genoa is October, with 218 mm of rainfall in just 13 days.

On November 15, 2014, the Bisagno torrent basin, which crosses the centre of Genoa, was hit by as much as 400 mm of rainfall, an anomalous event that caused human victims and material damage to the city. Although exceptional compared to average precipitation, the event could be repeated in the future with the same intensity and destructive force.

The surface of the Bisagno catchment area is 95 Km^2, the calculated precipitation flow rate is 38 million m^3 of water in a limited time to a few hours, besides there are numerous and large waterproofed surfaces. Applying a coefficient of 0.70 (precautionary), given the high concentration of structures and infrastructures, of waterproofed surfaces, it is possible to estimate about 65 Km^2 of surface potentially subtracted from the infiltration and absorption of land, with a potentially rushing volume of water of about 23 millions of m^3, not disposable by the system of urban manholes and sewers for the rapid occlusion of the same and immediate saturation due to excess of flow; a sort of bathtub whose tap remains open without control, after a few minutes there will be overflow. By reducing the R factor (surface water runoff) with the HCS system, the flow rate of runoff water would be significantly reduced. Assuming to apply a coefficient of 0.05 m 3 of storage volume in underground microinvases and diffused for every 100 m 2 of waterproofed surface. In this specific case the volume of water subtracted from R is:

$$Vwstox=Simp \times Cstox$$

Equal to a reduction of more than 120% of the dangerous rushing waters coming from the waterproofed surfaces, a surprising result.

In the specific case examined, a condominium building hosting 10 families, 4 floors, with waterproof surfaces of 1500 m^2 including the roof, the condominium square and access roads; it should realize an underground reservoir system as shown in Figure 9 for the storage of rainwater of 75 m^3.

In Italian cities, domestic consumption is on average around 200 litres/(ab • day); if the condominium examined hosts 30 inhabitants, the average daily consumption will be 3-5 m^3 with an autonomy of almost 2 weeks. With the HCS system there will be the side benefit of containing the consumption of drinking water, often inappropriately used to water the gardens, the small urban gardens and the toilets.

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The HCS system is made up of a series of "widespread discharge" on the entire territory at risk, for temporary storage and the subsequent gradual reuse of water for subsequent domestic and/or irrigation use.

Conclusions

The problem of "global hydrogeological" risk in Italy is a very complex problem whose solutions cannot renounce an inalienable geological modelling. The study of hydrogeological risk through complex mathematical models can lead to incorrect results if not correctly calibrated with respect to the local geological model. Italy is a very complex country from a structural and seism tectonic point of view. It is necessary to train citizens in a different way, more geological formation. The institutions must intervene with appropriate hydraulic works and land consolidation but also with appropriate urban planning tools. The HCS method allows, with the help and control of Municipalities and Regions, to significantly reduce and reduce the hydrogeological risk, especially in areas with a higher population density.

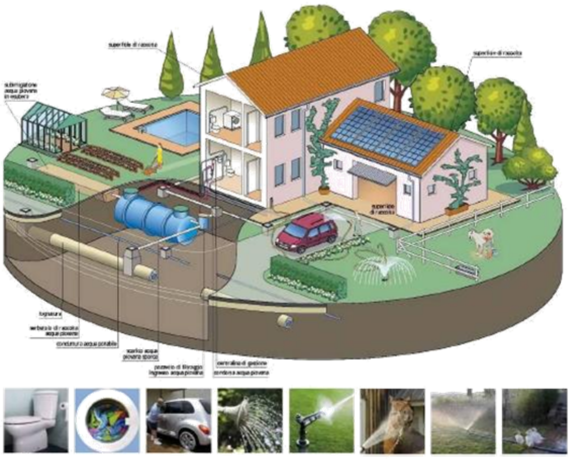

Figure 9: Storage and recycling of rainwater in a condominium building.

A parallel objective of this work is to encourage policy and research institutions to encourage the testing of the HCS method, a simple but effective control system with very low economic investments compared to those hitherto allocated for emergencies.

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