European Journal of Social Sciences Studies
ISSN: 2501-8590
ISSN-L: 2501-8590
Available on-line at: www.oapub.org/soc

DOI: 10.46827/ejsss.v8i3.1380 Volume 8 | Issue 3 | 2023

CLIMATE CHANGE, MITIGATION OF FLOODS AND DROUGHTS: ONLINE INFORMATIVE AND EDUCATIONAL RESOURCES[i]

Aldo Tommaso Marrocco[ii]
Professor,
Former Science Teacher,
"Istituto Comprensivo G. Toniolo",
Pisa, Italy

Abstract:
According to projections, in many regions of the world, heavy rains interspersed with long lasting dry periods are to be expected as a consequence of climate change, which requires adaptation strategies. In fact, dry soils have no time to soak heavy rains that fall quickly, the groundwater resources are not replenished and the aquifers are declining. At the same time, flood prone areas may suffer floods. Notoriously, this is already happening. In the meanwhile shrinking glaciers, and dam reservoirs that lose storage capacity as a consequence of sediment accumulation, further limit water availability downstream. In addition, coastal areas deprived of the sediments trapped in the reservoirs, undergo land losses; the Mississippi river delta has already lost 4,800 km², an area roughly the size of Delaware. The siltation of dam reservoirs can be mitigated; in this regard, several techniques are presented. The intensive exploitation of an aquifer, combined with a limited replenishment, may result in, e.g. land subsidence and seawater intrusion. Several techniques aimed at enhancing the recharge of aquifers, harvesting rainwater and saving water are presented in the article. Urban structures, such as rain gardens, bioswales, permeable asphalt and permeable pavements allow rainwater to infiltrate into the soil, thus recharging aquifers and mitigating overland runoff and floods. Several documents presented in the article deal with improving the liveability of cities, increasingly crowded and hot, thanks to a more efficient water management and planting trees. Our dietary choices, the clothes we wear and the food we waste have an influence on the overexploitation of water resources, sometimes in producing countries very far away from our country.

Keywords: liveability of the cities, runoff, infiltration, groundwater overexploitation, groundwater replenishment, rainwater harvesting, water saving

[i] CAMBIAMENTO CLIMATICO, MITIGAZIONE DI INONDAZIONI E SICCITÀ: RISORSE EDUCATIVE ED INFORMATIVE IN RETE

[ii] Correspondence: email aldo_marrocco@yahoo.it

Riassunto:
Secondo le previsioni, come conseguenza del cambiamento climatico molte parti del mondo avranno forti piogge intervallate da lunghi periodi di siccità. I suoli aridi non hanno il tempo necessario ad assorbire piogge intense non, permettendo così il ripristino delle falde idriche e causando inondazioni nelle zone a rischio. Notoriamente, questi cambiamenti stanno già accadendo; si rende così opportuna l'adozione di strategie di adattamento. Lo scioglimento dei ghiacciai nonché la perdita di capienza degli invasi idrici causata dall'accumulo di sedimenti, limitano ulteriormente la disponibilità di acqua a valle. Inoltre, le aree costiere private dei materiali che sedimentano negli invasi idrici subiscono fenomeni erosivi; il delta del fiume Mississippi ha già perso 4.800 km², una superficie doppia di quella della Sardegna. La sedimentazione negli invasi idrici può essere attenuata; l'articolo presenta vari documenti a questo riguardo. Lo sfruttamento intensivo delle falde idriche, associato ad un ridotto ripristino delle riserve, può portare a subsidenza ed intrusione marina. L'articolo presenta vari documenti su potenziamento del ripristino delle falde idriche, recupero acque piovane e risparmio idrico. Strutture urbane innovative come "Rain gardens" e "bioswales", nonché asfalto e marciapiedi permeabili permettono all'acqua piovana di infiltrarsi nel suolo ricaricando le falde idriche. Ciò attenua ruscellamento ed inondazioni. Vari documenti presentati nell'articolo trattano anche del miglioramento della vivibilità in città sempre più affollate e calde, grazie ad una migliore gestione delle acque ed alla piantumazione di alberi. Le nostre scelte alimentari ed i relativi sprechi, nonché gli abiti che indossiamo influiscono sullo sfruttamento delle risorse idriche nei paesi, talvolta lontani, dove questi sono prodotti.

Parole chiave: vivibilità urbana, ruscellamento e infiltrazione idrica, sovrasfruttamento e ripristino delle falde idriche, recupero acque piovane, risparmio idrico.

1. Aims of the teaching unit

The documents presented in this article are aimed at increasing knowledge and awareness on the possibility of mitigating the overexploitation of water resources, now exacerbated by climate change, dietary changes and growing population.

According to scientific and technical documents quoted in the article, a better management of water resources may mitigate their decline, while resulting in a reduction of, e.g. floods and soil subsidence.

2. Materials and methods

This article presents educational and informative resources, downloadable from the internet for free, that consist of text, videos, animations and images. Such documents can be used with the method felt by the teacher as most appropriate.

The article, unless otherwise stated, is based exclusively on the quoted documents.

3. Introduction

In some regions, as a consequence of climate change, future rainfalls are expected to come as heavy downpours interspersed with longer dry spells. This may result in an increased incidence of flooding, especially when combined with land use changes such as deforestation (1).

According to "Europe's climate in 2050", the climate of metropolises is aggravated by the urban heat island phenomenon that results in temperatures higher in the cities than in the countryside. This highlights the importance of our collective actions aimed at reducing the greenhouse gas emissions, while local adaptation strategies to the new climate conditions are adopted (2).

The urbanisation implies growing percentages of impervious surfaces that do not absorb water. Here, a heavy rainfall may result in a runoff exceeding the capacity of the drainage network, which potentially exposes the area to floods (3 fig. 2).

When the rain falls on impermeable materials such as granite, or on a ground that is hard and dry or already saturated with water, the infiltration does not occur and the water flows overland (4 Video). On steeply sloping soils as well the water has no time to infiltrate, and consequently flows over the surface of the land.

This also applies in the case of a downpour or a quick snowmelt consequent to rapidly warming conditions. When the water cannot infiltrate into the ground a flash flood may occur. Clearly, when the capacity of a river to carry the water is exceeded, the water flows out into the adjacent low-lying areas (5 Video).

The shrinking of glaciers may heavily affect the *ecosystems and the human communities* that rely almost entirely on glacial meltwater (1).

In high mountain Asia the meltwater is very important for both hydropower generation and agriculture, since during the dry periods it may compensate for drought downstream. By 2065, according to modeling studies, the contribution of glacial meltwater is expected to undergo a decline of 18% in the Ganges and 20% in the Brahmaputra (6).

The first image (6) shows the numbers of people living in each Himalayan river basin. In basins dominated by small glaciers, for instance in central Europe, over the next decades the amount of meltwater is expected to decline (6).

4. Loss of storage capacity in dam reservoirs consequent to the accumulation of sediments

Historically, people always tried to control and store excess water flows, or harvest rainwater. *Large dams have been built for both storing water and generating energy, while contributing to protect people from floods*. But, since the late 1990s, in many countries the development of new dams has been limited, due to concerns about environmental and socio-economic impacts (7).

At the same time, large amounts of sediment are accumulating in the reservoirs, which results in a loss of their storage capacity and a shorter useful life. While there is an increased demand for water storage and fewer sites suitable for new reservoirs, according to projections, the *existing global reservoir storage capacity will be halved by 2100 as a consequence of sediment accumulation* (8).

At the same time, the downstream river system and the coast are deprived of the sediments trapped in the reservoirs. Coastal areas rely on the sediment supply in order to face erosion. For instance, the Mississippi river delta has lost over 4,800 km^2 as a consequence of the loss of the sediment trapped in upstream reservoirs (8).

Here, historically, sediment deposition outpaced the natural subsidence, which resulted in coastal land gain. But, since 1850 in the lower Mississippi River the amount of sediments has decreased by more than 70% and, consequently, the natural subsidence is outpacing the sediment deposition. This is causing the disappearance of large areas of land below sea level (9> Land Loss).

In the Mississippi river delta, the previous loss of land is contributing to intensify the damage consequent to hurricanes (9> Hurricanes).

5. Avoiding the accumulation of sediments in reservoirs

Figures 1 and 2 (10) show, respectively, a fully silted reservoir and another that is filling much earlier than anticipated. The document also provides further information and images on minimising siltation and removing deposits.

Trapping of sediments by dams can be avoided or reduced, thanks to several techniques, each applicable in a range of different conditions. This could allow the reservoir storage capacity to become a renewable resource.

For instance, when the sediment concentration is low, the water of the river is allowed to enter into the reservoir. Conversely, *sediment-laden waters can be diverted and conveyed downstream* without entering the dam (8 figures 2-3).

Another technique, known as "sediment sluicing", consists in discharging *through the dam* the sediment-laden water during the periods of high inflows (8 fig. 6).

Differently, "Drawdown flushing" implies emptying the reservoir through low-level gates; the previously deposited sediments are re-suspended and scoured (8 fig. 8). The document also discusses some negative effects for the ecosystem that flushing operations imply, and their mitigation (8).

A document deals with techniques that prevent the adverse effects on the downstream ecosystem that may occur during flushing (11> France Génissiat).

Today many dams are planned without considering the problems inherent with sedimentation. As for the existing dams, an evaluation of the options aimed at improving sediment management is recommended (8).

A document deals with the removal of a cohesive sediment, that quickly accumulated in a Guatemalan reservoir, thanks to an innovative hydrosuction dredging system (11> Guatemala – El Canadá).

The website of the International Hydropower Association contains, inter alia, a video, animations (11> Strategies) and several case studies on this subject.

In California, a wildfire increased soil erosion in a catchment, which caused the accumulation of a large amount of sediments in a reservoir. This may help us to understand the important role that even soil management can play in this regard (8).

6. Wildfires and floods

Plants and litter layer of the forest soil break up the intensity of rainstorms and give time for the water to be absorbed (12).

But a wildfire may destroy this protection of the soil. In addition, the combustion of large amounts of such organic materials results in the formation of a gas that penetrates into the soil, and then condenses. This *creates a waxy coating that causes the soil to repel water and results in increased water runoff* (12).

The second image (13> Debris flow after wildfires) shows a bare hillside eroded as a consequence of runoff.

A debris flow is a slurry of water, soil, rocks, vegetation and boulders fast moving downhills. An animation shows a debris flow triggered by a rainfall event subsequent to a wildfire, that occurred upstream. A video shows a debris flow subsequent to a wildfire. Several other conditions may contribute to such potentially dangerous events, including steep slopes, heavy rainfall and earthquakes (13 / 13> Debris flow after wildfires).

Reseeding grass and mulching the soil are techniques used for reducing soil erosion, that may occur as a consequence of a rainstorm after a fire. Dead trees, felled and limbed, can be placed perpendicular to the direction of the slope to stop uncontrollable runoff (12).

A video contained in "Post-Wildfire Recovery" shows straw dams that often are placed in order to stop heavy runoff (14).

About 80% of the US water resources originate on forested land. Wildfires, besides increasing the susceptibility of watersheds to flooding, may also affect the quality of the water. In fact, a heavy rainfall event may move large amounts of suspended and dissolved material into downstream water supplies (15).

This may imply a shortened reservoir lifetime consequent to increased sediment loading, and changes in water chemistry that may harm local ecosystems and has implications for drinking-water treatment (15).

7. Groundwater

An educational website of the USGS contains text and images that may help students to learn about water cycle, surface water and groundwater. Some contents are available in several languages (16).

According to an FAO document, there is an increasing pressure on the global water resources consequent to demographic and economic growth, urbanisation, pollution and lifestyle (7).

According to "Groundwater Decline and Depletion", groundwater is an important resource on a global scale. When the water stored in the ground is abstracted at a faster rate than it is replenished, over time may result in groundwater depletion, lowered water table, decreased well yield, or even drying up of wells (17).

Groundwater discharges into a nearby water body whose surface is lower than the water table. Conversely, when the level of the water table is lower, the surface water seeps into groundwater (18 1st and 3rd images).

Importantly, the interactions between groundwater and surface water also include the exchange of solutes, *including contaminants*. This can affect the quality of the water (18).

When groundwater seeps into a streambed, it may provide a large contribution to the streamflow. Conversely, when a large amount of water is abstracted, the flow of groundwater into a river can be intercepted or even reversed. In this latter case a reduction of water in the river may occur; the same applies for lakes (17).

Overpumping of groundwater is one of the reasons why many large rivers, such as Indus and Colorado, do not reach the ocean (19).

When large amounts of groundwater are abstracted, the soil may collapse and subside (17), which may also imply an increased exposure to floods (20 Video).

8. Soil subsidence

"Land subsidence threatens to submerge the Mekong delta" contains a video. During the last 25 years, the delta started sinking 1-3 cm per year and in some places even 25-35 cm, which is very alarming for this area whose elevation is only 1-2 m above sea level (21). The Mekong delta is going to become more and more vulnerable to flooding, salinisation and coastal erosion. Groundwater extraction is a major cause of subsidence of this agricultural area, that produces food for almost 200 million people (21).

Other low-lying deltas in the world suffer from subsidence (21).

According to "Land Subsidence and Groundwater Management in Tokyo", here, most of the ground surface is covered by impervious surfaces and just a limited amount of rainwater can enter the soil to replenish the aquifer. Over a long period of time, the intensive exploitation of this latter combined with a limited replenishment resulted in both a lowered water table and a subsidence rate up to 24 cm/year in 1968 (22).

After reducing and regulating the exploitation of the wells, the water table started rising again (22 figures 1 and 2), and at the same time, the rate of subsidence of the city slowed dramatically.

In Tokyo, the Government encourages people to use water efficiently, and *requests that the installation of pumping facilities also include water infiltration facilities*. In order to promote groundwater recharge, conserving green areas and farmland is necessary (22).

A research carried out in 99 coastal cities has found that in most of them, part of the land is subsiding at a rate faster than sea level rise (23 fig. 1). Among the causes, there are oil extraction and even the load of new buildings; but the most important, is likely to be groundwater extraction, which may accelerate sediment and aquifer compaction. The fast subsidence that Jakarta and Shanghai exhibited in the past has recently slowed, thanks to governmental interventions aimed at reducing groundwater extraction (23).

According to Famiglietti J.S. (19), despite the critical importance of groundwater, this resource is often overlooked as compared to surface water supplies. Groundwater resources are poorly monitored and managed, and their consumption often occurs at rates higher than their replenishment.

Some countries subsidise the pumping costs in order to promote agricultural productivity, while neglecting the falling aquifer levels. The situation can be compounded by climate change, growing population, rising demand for food and energy (19).

Most of the existing water laws and policies, written long time ago, do not consider the interconnections between surface waters and groundwater, that are treated as disconnected entities. While many international agreements aimed at sharing the water of rivers and lakes exist, generally, this does not apply to groundwater. However, a recent international agreement for the management of the Guarani aquifer in South America, provides an important example of what can result from an open dialogue (19).

9. Seawater intrusion

In coastal areas, the growing use of groundwater is resulting in aquifer depletion and consequent intrusion of sea water (7).

An aquifer can be artificially recharged in order to create a barrier against seawater intrusion (24).

Three images show the evolution, A. from an historic situation, B. to seawater intrusion consequent to pumping and finally, C. to the injection of high-quality freshwater into the aquifers aimed at stemming the intrusion (25).

The Potomac aquifer is naturally recharged by precipitation only at a narrow location and, after long overexploitation, the water level has dropped, the soil is subsiding and saltwater intrusion is occurring in nearby coastal areas. The Potomac aquifer will be recharged by using wastewater that has been *treated to meet the drinking water standards*. This is expected to stop subsidence and saltwater intrusion (26>Videos> Swift Research Center: What is the Potomac Aquifer?).

The website is rich with links and explanations, including the wastewater treatment process (26>HRSD's Highly Treated Water: The Wastewater Treatment Process).

10. Recharging aquifers, rainwater harvesting and water saving in urban areas

Aquifer storage and recovery consists in storing water underground during wet periods for recovery when this is necessary, for instance during dry seasons. The quality of the water used for this purpose should comply with the existing or anticipated ground water uses. This may also include complying with drinking water standards (24).

The document discusses scientific and technical issues related to aquifer storage and recovery (24). By-products, whose formation may occur when the water is disinfected before injection into the aquifer, should be taken into account. Even the reactions between groundwater and recharge water should be accounted for. Elevated concentrations of dissolved solids should also be considered.

Aquifer storage and recovery in seismic areas, where poorly consolidated soils are combined with a very shallow water table, may imply the risk of soil liquefaction (24). Two Indian educational videos show how the rain falling on rooftops, gardens and parks, can be used to replenish aquifers (27 / 28).

According to Want S., urban water advisor (29 Video), it is important to use the right water for the right purpose which, for instance, means not using the precious drinking water for park irrigation and flushing toilets.

In this regard, a Pakistani document deals with rain-water storage tanks for new housing schemes (30); other documents deal with water saving at home (31 / 32 Video).

In order to prevent damages in case of earthquake, the weight of the water tank, if placed on top of the building, need to be accounted for in the design (33 fig. 10).

Two videos show rainwater harvesting tanks placed in elementary schools (34 / 35). This rainwater is not drinkable (35).

A Californian document deals with water saving and fire safety in the garden (36> Protect Your Home From Wildfires and Conserve Water During CA's Drought). Fire resistant mulch, such as stone or rock within 5 feet of the home, can reduce moisture loss from the soil while helping in the prevention of fire damage.

Figure 12 (3) shows a multipurpose detention basin, generally used as a sport court, this area may temporarily store surface runoff, and subsequently release it.

A video shows a water square in Rotterdam; in the basins found here, when the weather is fine, the people can exercise or sit quietly. When a heavy rainfall occurs, the water is stored in these basins and this may prevent the area from flooding. Subsequently, this water is used for plant irrigation (37).

11. Rain gardens and bioswales

The substitution of pervious surfaces of the natural landscape for impervious surfaces of urban areas implies an altered water cycle, reduced absorption, increased surface runoff, and related consequences (3 fig. 2 / 38 video). This situation can be changed; the animation shows urban structures, such as permeable paving, swales, tree pits and rain gardens that may absorb and store rainwater, thus countering the runoff (38 Video).

The runoff from the roof, driveway and open areas is directed into the rain garden that consists of a small depression planted with flowers and ornamental grasses. The rain garden is designed to temporarily hold the rain water, which infiltrates into the soil and *disappears within 48 hours* (39 Text and Video).

This document is linked to an interactive publication that contains images, videos, animations and slideshows aimed at supplementing the information (39> Rain Garden Design Guide).

An image shows a rain garden in New York City (40). The larval development of mosquitoes requires at least 48 hours in standing water. For this reason, even here the rain gardens are designed to drain within 48 hours (40> Rain Garden FAQ's).

Figures 1-2-3 (41) show swales, used to manage stormwater runoff while recharging the groundwater table. In a swale, the soil can be amended with sand in order to increase water infiltration. In sites with poorly drained soils, an underdrain may be required to remove excess water during peak flows.

12. The "Urban heat island effect" and the life quality in our cities

In fig. 1 a thermal image shows an urban heat island; in fig. 2 we can observe the diverse temperatures consequent to different land uses (42> Heat Islands Compendium >Chapter 1). The physical properties of the materials typically found in the built-up environments contribute to the higher temperatures observed in urban areas (42> Heat Islands Compendium).

According to projections, over the next decades, the world's urban population will grow while the temperature is expected to increase (2 Video); clearly, improving the liveability of our cities is of vital importance.

According to the document of US Environmental Protection Agency, thanks to shade and evaporation, trees and vegetation may reduce the heat island effect. For instance, shading may reduce by 11-25°C the temperature of a surface and, in suburban areas, mature trees reduce the temperatures by 2-3°C compared to new suburbs without trees (42> Heat Islands Compendium> Chapter 2).

Trees correctly placed and vegetation may enhance the thermal comfort in buildings, thanks to their shade in summer, and the protection from cold winds in winter. This results in reduced energy expenditure (42> Heat Islands Compendium> Chapter 2 figures 3-5-6-14).

A document studies the role of street trees in improving the thermal comfort in Melbourne, and discusses pros and cons (43). According to the paper, the cooling benefit which trees provide depends on several variables, including the geometry of the street, and local meteorological conditions. This study may suggest the best strategy in selecting and planting trees, thus maximising the shade area, without restricting nocturnal cooling and ventilation.

A potential adverse effect of vegetation is the increase in atmospheric moisture consequent to evapotranspiration (43 / 42> Heat Islands Compendium >Chapter 2).

However, the beneficial effect of trees outweighs certain negative impacts; adequate amounts of water for the trees is of paramount importance for health, transpiration and development of full canopies (43).

A website deals with the importance of water for the quality of life in Melbourne, where green spaces contribute to keeping cool the microclimate of the city (44).

This Australian city underwent a long drought period, between 1997 and 2009, which led to water restrictions resulting in detrimental effects on the health of the trees (43 / 44> Video). After the drought, the city undertook projects aimed at improving water harvesting and passive irrigation (44> Video).

The adaptation approach of Melbourne to the changing climate includes doubling the urban forest canopy cover by planting 3,000 trees every year (29 Video).

Nowadays, here, raingarden tree pits, permeable asphalt and permeable pavements are designed for intercepting the stormwater runoff, thus providing passive irrigation of trees (44> Raingardens> Raingarden tree pit program / 44> Permeability and infiltration).

Two US videos show the absorption performances of, respectively, a porous asphalt and a pervious pavement (45 / 46> Pervious Pavement a Cost-Effective Alternative for City Streets).

13. Water footprint of food

The volume of freshwater used in the production process of a product is the water footprint of the product itself (47).

The *grey water* footprint is the volume of freshwater that is required to dilute a polluted water resulting from a production process, so that the discharge water complies with the required quality standards. This may help to understand the impact of pollution on water resources (47).

The world population is growing, per capita food consumption is increasing in many areas. Between 2006 and 2050, an increase from 2,650 to above 3,000 kcal/person/day is expected. In addition, there is an increasing consumption of meat and other animal products, whose production requires more water than vegetable products (7).

For instance, the water footprint of a calorie provided by cereals or starchy roots is 20 times smaller than for beef. Whereas the water footprint per unit of protein is 6 times smaller for pulses than for beef (48).

Text, images and a video on water footprint are available (49>School resources >Presentation >AquaPath Video).

Figure 1 (47) shows the water footprint of different food products.

Figure 2 (48) shows the water footprint of selected crops and animal products.

According to this article, feeding the world requires dietary changes and reduction of food waste and food loss.

14. Food wastage

According to FAO estimates, between the field and the end user, food lost or wasted is around 30 percent (7 from page 48).

According to "Food wastage footprint - Impacts on natural resources", on a global scale, the amount of water used to *produce the food, which subsequently is wasted, equals the amount of water discharged by the Volga river*. The land vainly used for producing such uneaten food occupies about 1.4 billion hectares of land, and the economic damage of food wastage, excluding seafood, is US$ 750 billion (50).

As a general rule, in developing countries most losses occur during the agricultural production. Conversely, in middle- and high-income countries food waste is higher at retail and consumer stages; here it accounts for 31-39% of total wastage and is mostly driven by overpurchasing (50). The document discusses the options available to address the causes of wastage.

An educational video deals with food wastage (51).

15. An example of water footprint of textile products

Nowadays, according to a study reviewed in the document (52), the volume of water necessary for producing the cotton goods imported in the UK is estimated to constitute 1.7% of the total per capita water footprint for this country.

A study conducted in the field of sustainable consumption compares the production of cotton, hemp and polyester. The document analyses water and energy requirements, CO2 emissions and ecological footprint (52).

Hemp, now replaced by cotton, was a traditional fibre in Europe, where it played an important role in the production of textiles. Hemp requires low maintenance and few agrochemicals; producing 1 kg of hemp requires between 2,401 and 3,401 kg of water, whereas 1 kg of cotton requires 9,758 kg of water (52).

16. Consequences of water intensive agriculture in arid regions

An educational website entitled "Case Study: The Shrinking Aral Sea" deals with the consequences of water intensive agriculture in Central Asia.

In this desert climate large amounts of water from the Amu Darya and Syr Darya rivers are used to irrigate water-intensive crops, especially cotton. This caused the Aral Sea to drop 23 metres (53 Text and video).

This former resort, where commercial fishing catches amounted to 43,340 tons in 1960, *now is a desert*. This 45,000 square kilometres area is unhealthy for animals and people because heavily polluted by the agrochemicals previously used in the intensive agricultural activities (53 / 53> Previous Page> Aral Sea Crisis – An in-depth article from Columbia University).

Cotton production requires large amounts of water and chemicals that remain in the environment and mix with groundwater. Here, the agricultural production should be diversified, and the irrigation system modified, in order to reduce water consumption (53> Previous Page> Aral Sea Crisis – An in-depth article from Columbia University).

The agricultural trade between countries can play an important role in this regard. For instance, a country affected by water scarcity may import the water-intensive products, while exporting goods and services that require less water in their production (7).

For example, Mexico is a maize importer, which saves 12 billion cubic metres per year of its own water resources (49 >Read more on virtual water trade), notoriously limited.

17. Water pollution

The pollution reduces the amount of available water and has a high cost to human health; some impacts can be irreversible. In some countries, the 'polluter pays' principle has stimulated changes in attitudes towards pollution. There are technologies that may limit agricultural water pollution, such as integrated pest management and plant nutrition management. Incentives and subsidies combined with stringent regulation and enforcement, may contribute in reducing water pollution. The payment for environmental services may also contribute in reducing the agricultural pollution and in saving money for water treatment downstream (7).

"Water Contamination Animation" is a video showing how groundwater contamination in an agricultural area may occur; this is intensified by drought conditions (54).

The video also shows domestic wells drying up when working in competition with deeper wells that lower the water table.

A video shows contaminants entering an aquifer; here, according to density, they may float or not. In the video, we can observe what may ensue from the contamination (55).

18. Water and land use

"Our World in Data" provides graphs and interactive maps on water use and stress, information per capita, by sector and by country. Globally, about 70% of water withdrawals is used for agriculture (56).

Global groundwater withdrawal has grown from 100–150 km^3 in 1950 to 950–1000 km^3 in 2000; this is causing depletion of aquifers, pollution of groundwater and in some cases saline intrusion in coastal aquifers (7).

Between 2012 and 2050 an increase in agricultural production by almost 50% is expected (48).

Water irrigation schemes, as well as urban distribution networks, often lose large amounts of water through leakage and percolation and are not efficient (7). In rainfed conditions, farmers may encourage infiltration and storage of water in the soil, at the same time reducing runoff (7).

An educational document deals with water infiltration in the soil (57).

According to "Comparing infiltration rates in soils managed with conventional and alternatives farming methods: A meta-analysis", the ability of the soil to retain water is important for both crops and flood prevention (58). Fig. 4 shows the infiltration rate observed in five alternative agricultural practices compared to conventional controls.

Trees and other perennial plants, thanks to root growth and decomposition contribute to soil porosity, which enhances water entry into the soil (58).

The presence of livestock may reduce the infiltration rate, which could be related to the removal of vegetative cover and the compaction of the soil consequent to the activity of animals. Conversely, a low grazing intensity has been associated with improved water infiltration (58).

Rice fields may have the function of holding the water during heavy rainfall, thus mitigating or preventing floods. In addition, rice fields may recharge aquifers, thus reducing the subsidence observed in coastal areas (59 pages 9 and 10).

Figures 1 and 8 (60> Case study 23) show rice fields intentionally flooded in order to enhance groundwater recharge; the farmers receive a payment for the ecosystem services. "Managing Aquifer Recharge – A Showcase for Resilience and Sustainability" is an UNESCO publication that contains 28 experiences from different parts of the world (60).

Irrigation water should be used sparingly, in order to avoid waterlogging and subsequent salinisation, which may occur in arid or semi-arid climates (7).

Woody debris accumulation against river bridges poses potential hazards for their stability and increase the risk of flooding of adjacent areas (61 image of page 1, and figures 1 and 2 / 62 1st image and 1st drawing).

According to a BBC video, a village was flooded because some felled trees , after entering a watercourse, blocked a culvert. This suggests the importance of a correct land management aimed at flood prevention (63 > video / 63 image).

Acknowledgement
The author would like to thank Dr. Liu Lin for information kindly provided.

Conflict of Interest Statement
The author declares no conflicts of interest.

About the Author
The author is a former middle school teacher, and wrote about 65 educational papers starting 35 years ago. Areas of interest: Health Education, Environmental Education and Prevention of Natural Disasters. The author has a University Degree in Biology.

References

1) University Corporation for Atmospheric Research, (2022). Climate Change: regional Impacts. https://scied.ucar.edu/learning-zone/climate-change-impacts/regional
2) CNRS, (2021). Europe's climate in 2050. Video https://www.bing.com/videos/search?q=climate+change+predictions&docid=607989867113637914&mid=E9C6102E93B01610895AE9C6102E93B01610895A&view=detail&FORM=VIRE
3) World Meteorological Organisation, (2008). Urban Flood Risk Management – A Tool for Integrated Flood Management. https://library.wmo.int/doc_num.php?explnum_id=7342
4) GCSE Geography, (2016). Causes of Flooding – How are Floods Caused? https://www.youtube.com/watch?v=8zhBISqeGqA
5) Bureau of Meteorology, (2019). Understanding Floods. https://www.youtube.com/watch?v=ivUKLr8q4sE
6) Davies B., (2022). Glaciers as a water resources. https://www.antarcticglaciers.org/glaciers-and-climate/glacier-recession/glaciers-as-a-water-resource/
7) FAO, (2008). Coping with water scarcity. https://www.fao.org/3/i3015e/i3015e.pdf
8) Kondolf G.M. et al., (2014). Sustainable sediment management in reservoirs and regulated rivers: experiences from five continents. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013EF000184
9) Restore The Mississippi River Delta, (2022). Our Coastal Crisis. https://mississippiriverdelta.org/our-coastal-crisis/
10) Healy K.M. et al.. State of the Practice of Sediment Management in Reservoirs: Minimizing Sedimentation and Removing Deposits. https://acwi.gov/sos/pubs/3rdJFIC/Contents/Posters-Healy.pdf
11) International Hydropower Association, (2022). Sediment Management. https://www.hydropower.org/sediment-management
12) Colorado State University Extension. Soil Erosion Control after Wildfire. https://extension.colostate.edu/topic-areas/agriculture/soil-erosion-control-after-wildfire-6-308/
13) Washington State Department of Natural Resources, (2022). Wildfire-Associated Debris Flows. https://www.dnr.wa.gov/wildfire-debris-flows#what-is-a-debris-flow
14) CAL FIRE, (2019). Post-Wildfire recovery. https://www.readyforwildfire.org/post-wildfire/after-a-wildfire/
15) USGS, (last modified 2018). Water Quality after Wildfire. https://ca.water.usgs.gov/wildfires/wildfires-water-quality.html
16) USGS, Water Science School. https://www.usgs.gov/special-topics/water-science-school https://www.usgs.gov/special-topics/water-science-school

17) USGS, (2018). Groundwater Decline and Depletion. https://www.usgs.gov/special-topics/water-science-school/science/groundwater-decline-and-depletion
18) USGS. Sustainable Groundwater – Interconnected Surface-Water Depletion. https://ca.water.usgs.gov/sustainable-groundwater-management/interconnected-surface-water-depletion.html
19) Famiglietti J.S., (2014). Commentary : The global groundwater crisis. https://web.mit.edu/mission/www/m2018/pdfs/groundwatercrisis.pdf
20) Sunarts Production, (2017). 04 Groundwater and Land Subsidence (Eng Sub). https://www.youtube.com/watch?v=9UdxzPsWYt4
21) Minderhoud P., (2017). Land subsidence threatens to submerge the Mekong delta. https://www.uu.nl/en/news/land-subsidence-threatens-to-submerge-the-mekong-delta
22) Chikafusa S. et al., (2006). Land Subsidence and Groundwater Management in Tokyo. https://www.iges.or.jp/en/publication_documents/pub/peer/en/1208/IRES_Vol.6-2_403.pdf
23) Wu P.-C. et al., (2022). Subsidence in Coastal Cities Throughout the World Observed by inSAR. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022GL098477
24) USGS, (2018). Aquifer Storage and Recovery. https://www.usgs.gov/centers/california-water-science-center/science/aquifer-storage-and-recovery#overview
25) USGS. Sustainable Groundwater - Seawater Intrusion. https://ca.water.usgs.gov/sustainable-groundwater-management/seawater-intrusion-california.html#model
26) HRSD. SWIFT. https://www.hrsd.com/swift
27) Bodhaguru, (2012). How to recharge underground water. https://www.youtube.com/watch?v=sH8XmG1Bvz8
28) Biome and LabourNet, (2017). Rainwater Harvesting: Groundwater Recharge. https://www.youtube.com/watch?v=3PPYC7qM0XY
29) City of Melbourne. Adapting to a Changing Climate – Melbourne's Story. https://urbanwater.melbourne.vic.gov.au/tours-videos/videos-and-animations/video-adapting-our-city-to-climate-change/
30) International Water Management Institute, (2021). Urdu Point: Country Representative Of IWMI Suggests Rain-water Storage Tanks For New Housing Schemes https://www.iwmi.cgiar.org/2021/10/urdu-point-country-representative-of-iwmi-suggests-rain-water-storage-tanks-for-new-housing-schemes/
31) Nainar N., (2020). A washbasin helps reuse grey water. https://www.thehindu.com/news/cities/Tiruchirapalli/a-washbasin-helps-reuse-grey-water/article31780071.ece

32) CIRIA, (2013). Water sensitive urban design (WSUD) in the UK. https://www.youtube.com/watch?v=cv8dfBn_c-4
33) Structural Engineering Forum of India. Steps for safe design and construction of multistorey reinforced concrete buildings. https://www.sefindia.org/rangarajan/SEISMICSTEPS/Steps_for_RCC_design_10.01.08.pdf
34) Permasystems, (2017). Rainwater Harvesting at Elementary School Garden in San Diego. https://www.youtube.com/watch?v=rtkW7KbTKtw
35) Rain Ranchers, (2016). Basic Components of a Rainwater Harvesting Tank. https://www.youtube.com/watch?v=3wFkzNCs6E0
36) Save Our Water, (2022). Save Water. Save California. https://saveourwater.com/en/?gclid=EAIaIQobChMIsOiU_smt-QIVis53Ch1PYgFVEAAYASAAEgInjPD_BwE
37) Schenk J., (2021). Water square in the city of Rotterdam. Video https://www.youtube.com/watch?v=h-Naqi6TmSU
38) CIRIA, (2013). Ever wondered where the rain goes? Sustainable drainage animation. https://www.youtube.com/watch?v=LMq6FYiF1mo
39) University of Nebraska-Lincoln, (2022). Rain Gardens. https://water.unl.edu/article/stormwater-management/rain-gardens
40) New York City Government, (2022). Green Infrastructure – Rain Gardens. https://www1.nyc.gov/site/dep/water/rain-gardens.page
41) Clemson University Cooperative Extension, (2015). An Introduction to Bioswales. https://hgic.clemson.edu/factsheet/an-introduction-to-bioswales/
42) US Environmental Protection Agency, (Last updated 2022). Using Trees and Vegetation to Reduce Heat Islands. https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands
43) Coutts A. et al., (2015). Temperature and human thermal comfort effects of street trees across tree contrasting street canyon environments. https://www.researchgate.net/publication/271842809_Temperature_and_human_thermal_comfort_effects_of_street_trees_across_three_contrasting_street_canyon_environments
44) City of Melbourne. Urban water – Discover how water creates a liveable city. https://urbanwater.melbourne.vic.gov.au/
45) Grain & Son/Maryland Paving Inc., (2013). Porous Asphalt Demonstration. https://www.youtube.com/watch?v=I16WGau3jxE
46) US Environmental Protection Agency, (last updated 2022). Soak Up the Rain; Permeable Pavement. https://www.epa.gov/soakuptherain/soak-rain-permeable-pavement
47) Hoekstra A.Y. The water footprint of food. https://waterfootprint.org/media/downloads/Hoekstra-2008-WaterfootprintFood.pdf

48) Mekonnen M.M. and Gerbens-Leenes W., (2020). The Water Footprint of Global Food Production. https://www.mdpi.com/2073-4441/12/10/2696
49) Water Footprint Network. National Water Footprint. https://waterfootprint.org/en/water-footprint/national-water-footprint/
50) FAO, (2013). Food wastage footprint – Impacts on natural resources. https://www.fao.org/3/i3347e/i3347e.pdf
51) Climate Science, (2022). Food Waste: We need to Stop Wasting 30% of our Food. https://climatescience.org/advanced-food-waste
52) Cherrett N. et al., (2005). Ecological Footprint and Water Analysis of Cotton, Hemp and Polyester. https://mediamanager.sei.org/documents/Publications/SEI-Report-EcologicalFootprintAndWaterAnalysisOfCottonHempAndPolyester-2005.pdf
53) TERC, (last modified 2017). Case Study: The Shrinking Aral Sea. https://serc.carleton.edu/eet/measure_sat2/case_study.html
54) Community Water Center, (2017). Water Contamination Animation. https://www.youtube.com/watch?v=sS4V2Vdi9zM
55) GroundwaterU, (2021). Groundwater Contamination for Beginners | Groundwater Plume Simulation and Visualization. https://www.youtube.com/watch?v=5EhgdJpDKco
56) Our World in Data, (Revised 2018). Water Use and Stress. https://ourworldindata.org/water-use-stress
57) USDA, (2014). Soil Infiltration. https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20Infiltration.pdf
58) Basche A.D. and DeLonge M.S., (2019). Comparing infiltration rates in soils managed with conventional and alternatives farming methods: A meta-analysis. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0215702#pone-0215702-g005
59) Matsuno Y. et al., (2002). Accounting of Agricultural and Nonagricultural Impacts of Irrigation and Drainage Systems: a Study on Multifunctionality in Rice. http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR43.pdf
60) UNESCO, (2021). Managing Aquifer Recharge. https://www.iges.or.jp/en/publication_documents/pub/bookchapter/en/11833/379962eng.pdf
61) Cantero-Chinchilla F.N. et al., (2018). Assessing the effects of debris accumulations at river bridges. http://hydro.soton.ac.uk/wp-content/uploads/sites/297/2018/09/BOOKLET_DEBRIEF_PROJECT.pdf
62) Gschnitzer T. et al., (2015). Towards a robust assessment of bridge clogging processes in flood risk management. https://pdfs.semanticscholar.org/dcd8/523c4eacfab1a769a6996a8a5b97e9da4fce.pdf
63) BBC, (2020). Storm Dennis: Pentre flooded again after tree felling. https://www.bbc.com/news/uk-wales-51561865