



Anticipating a decrease in water resources

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Water resources will be severely affected by climate change. It is vitally important that we reduce consumption and establish sustainable management for this fragile and limited resource.

Water resources will inevitably be modified by global warming. This will naturally affect the five major areas of water use: agricultural (irrigation), industrial, household, recreational and environmental activities. But what will the impact be on the volume of available water? Will changes in the management of water resources be needed and how can we proactively prepare for these eventual changes?

Rising temperatures will have multiple consequences, often linked, on this limited resource. The first change will be in an altered geographical distribution of rainfall, as temperature increase will be less pronounced near the equator than it will be at the poles. Indeed, at the global scale, thermal gradient are associated with circulating air masses, and subsequently, with transported heat and winds blowing at middle latitudes. In Europe, by 2050, rainfall is expected to have declined in southern regions and increased in northern regions.

Moreover, with this increase in temperature, the atmosphere will contain more water vapor, which disturbs rainfall patterns. In the temperate and

humid zones, this will translate into an increased frequency of heavy rainfall (more than ten millimeters per day) - one trend already being observed across the continents. Dry regions, conversely, will see the rise in temperature result in a decreased frequency of rainfall as the precipitation threshold will be higher than it is today.

Blue and green water

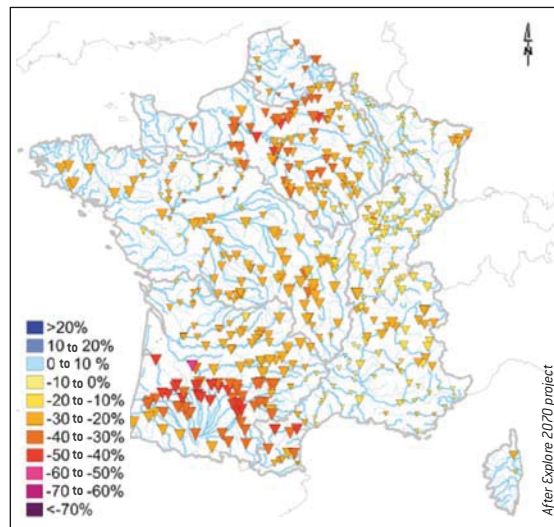
An excess of water present in warmer air results from an increased water exchange with the earth's surface as more water evaporates. This increased "evaporation demand" is easily met over oceans. It is more limited over the continents, where evaporation originates mainly from vegetation, which draws water from the soil. This is referred to as "green water", contributing to the production of biomass through the process of photosynthesis. The other form of water is called "blue water". We find this in lakes, streams, groundwater and wetlands. It is "blue water" that is used for producing drinking water, and for industrial and agricultural uses.

However, whether the water is blue or green, it originates from rain and the two types of water are therefore interdependent: an increase of green water will cause a decrease of blue water. In France, it is estimated that climate warming will cause an annual decrease of up to 20 to 30 percent of blue water by 2050 (see the map on this page). Droughts, which will occur more frequently and will last for longer periods, are expected to occur, without decreasing the risk of flooding. On the contrary, flooding risk could even increase in certain regions, such as the south of France.

Possible adaptations

How can we adapt to these predicted changes? A first adaptation route consists in implementing a supply policy - namely, by offsetting future shortages through the use of new resources. To do this, we could develop collection systems such as ground water pumping and river diversion. We could also build new desalination plants, dams and artificial reservoirs used to store rainwater. Such infrastructures could prove necessary for maintaining irrigation in key agricultural sectors, as well as inland waterway transport (for example on the Rhine or the Danube), but also for preserving the safety of nuclear power plants, which require large amounts of water to operate.

A strategy aiming at developing the use of blue water and water generated from 'grey' water treatment stations - wastewater - (through recycling) involves large-scale financing. In France, its implementation would be the responsibility of water agencies, of public river-basin territorial institutions and of development companies. The financial aspect is not the sole difficulty that these institutions would face. Beyond production and consumption activities, evaluation



Expected impacts of climate change on the mean annual flow of French rivers. The averages from 2046 to 2065 are compared to those from 1961 to 1990. The results show that the south west and north regions are expected to suffer declines of around 50 percent. The size of the triangles indicates the degree of confidence based on the mean of 14 different simulations.

of the collective interest of the new infrastructures will need to integrate both ecological and environmental considerations. As such, opposition to the Charlas dam in the Midi-Pyrenees region, dating back nearly 30 years, illustrates how such projects could likely exacerbate local conflicts.

Development projects are generally subjected to analyses that balance construction costs against expected benefits. The construction of the Renaissance dam on the Blue Nile in Ethiopia, which began in the spring of 2013, was the subject of such a cost-benefit analysis that detailed the financial aspects (related to investments and to population displacements), seismic risks, as well as expected profits that would come from hydroelectric production and the extension of irrigated surfaces. This type of analysis acts as a decision support tool, supplementing public utility enquiries, parliamentary reports and feasibility studies. All these actions may contribute supporting the choice between different scenarios: no change, launching new projects or implementing alternative measures.

This form of adaptation presents limits nonetheless. Irrigation alone will not solve all difficulties facing agriculture. Overexploitation of groundwater, lakes and rivers could lead to their temporary disappearance, like the case of the Aral Sea, in Central Asia, which lost some 90 percent of its volume between the 1960's and the mid-2000s. Drying of water systems is often accompanied by the decline of terrestrial and aquatic ecosystems, as well as ground movements.

In addition to risks associated with drought, this type of adaptation exacerbates our dependency on water resources and decreases our resiliency to climate extremes.

Public authorities have gradually realized that the mobilization of new resources should be associated with regulatory measures. They consist, notably, in limiting our dependence on the resource. One of the key elements is existing competition between green and blue water, since increased consumption of the first reduces the second - which is distributed in water systems.

Reducing consumption

Agricultural production systems have already begun implementing changes to decrease water consumption. One approach aims to modify sowing or harvest periods to allow crops to adapt to changing seasonal temperatures. Another method is to shift to crop species that consume less water, such as soybean or sorghum.

More generally, agro-ecology and its more recent alternative, ecologically intensive agriculture, appear to be promising as solutions for adapting agriculture to global changes while responding to growing demand for quality products. These approaches specifically address increasing production while respecting human health

and maintaining balanced ecosystems. They rely on naturally occurring ecological functioning, such as diversity of crops or beneficial organisms to limit the proliferation of pests. Another example of ecologically intensive agriculture is direct seeding or seeding under a permanent vegetative cover. Through a deep and powerful root

system, this vegetative cover favors the upward movement of nutrients to the surface where they are then used by the primary crops. Rainwater runoff also decreases. Important sources of biomass can thus be produced with less water, notably during dry seasons.

These new practices can nevertheless lead to increased competition

for water resources, as for example in agroforestry, where tree plantation is directly linked to the exploitation of arable land. To optimize these practices, a series of approaches will need to be integrated, including agronomic, economic, hydrological, health and environmental approaches. This integration may be performed using numerical simulations, which make it possible to develop change scenarios by offering a range of possible biotechnical adaptation measures. In addition to this virtual approach, adaptation will be possible by directly involving stakeholders in creating experimental systems for farmers, encouraging them to take full advantage of current developments.

To support adaptation by limiting our dependence to water resources, various actions can be deployed, some of which are already in place in Europe. They concern the residential sector and semi-arid regions. These actions include pricing policies adapted to the scarcity of the resource, regulatory restrictions, as well as awareness-raising policies and financial support for investments in more water-efficient equipment.

Studies have shown that the awareness of users with respect to the cost of resources is often quite low, but that it is increasing rapidly with access costs - as much or even more when coupled with restrictive measures. Clearer information provided with water bills has proven to be particularly important for transmitting a strong message about the scarcity of the resource. It has also been observed that anticipated higher access costs related to a scarce resource often encourages users to invest in more water efficient equipment.

Similarly, farmers who practice irrigation should be able to anticipate climatic scenarios and change for more suitable production systems, especially considering that since 2006, standardized European compensatory aid has been implemented: farmers have



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Built on the Naryn River, tributary of the Syr Darya River near the Uzbek border, Taktogul dam is the largest in Kyrgyzstan.

A source of cooperation more than conflict

The geopolitics of water is often presented as a competition between countries for a resource viewed as a strategic element and a source of conflict. This competition concerns countries located along waterways or those who share groundwater resources. But over the past 50 years, thanks to intergovernmental relations, cooperative solutions were found for a majority of these cases.

Consequently, Ariel Dinar, of the University of California, Riverside, and Praddep Kukulauriya, one of the United Nations Development Program experts, showed that structural scarcity for this resource plays a positive role in fostering cooperation between states. Other factors, such as sound governance and international trade, often carry more importance than geographical considerations. On the other hand, cooperation agreements often incorporate other factors, including hydro electrical production, flood protection and pollution control.

The agreement for the Sir Darya river concerns, for example, three Central Asian countries: upstream, Kyrgyzstan; and downstream, Uzbekistan and Kazakhstan. As part of an agreement inherited from the Soviet model, the country located upstream is committed to providing electricity and water for irrigation purposes in exchange for oil supplied by the countries located downstream.

There exist more than 200 cross-border waterways worldwide, some of which are the subject of international agreements in the context of resource scarcity. Their stability could be called into question by climate change. In 2008, economists observed that resource-sharing agreements were stronger than the importance of the waterways they protected, and, conversely, that fluctuating water flows tended to exacerbate tensions. It is therefore essential to determine rules of sharing universally considered by the various concerned countries as fair, as well as compensation mechanisms adapted to both economic and climatic changes.

less incentive to select irrigated crops for substantial yields, such as corn. Crop substitutions can therefore be developed more easily. However, they will need to rely on territorial development of agricultural sectors or viable exports. Corn could be replaced by sorghum for animal feed, but French industry remains to date poorly structured in this sector.

Extreme events

Regardless of the adaptation strategy we decide on, it will also be needed to adapt to extreme climatic events whose frequency and intensity will certainly increase. We can decide between two strategies: to avoid or to accept. To cope with flooding risk, avoidance strategies involve the creation of reserve basins upstream of rivers; in urban areas, we could use porous material (gravel or bitumen for draining) for sidewalks and pavements, enhance rainwater collection, and designate expanded flood zones (which help to prevent flooding downstream, but which require flooding of agricultural land upstream).

Adaptation to drought can be accomplished by reducing our dependency levels but also by creating secure resources (dams) or use methods for artificially replenishing groundwater, whose stored water could be used in times of crisis (one such possibility is currently being considered for the Seine river basin).

With regard to acceptance strategies, they are intended to transform urban areas susceptible to flooding, which translates into constructing on stilt systems (as, for example, in Bangladesh) or developing "floating" housing (as in the Netherlands) and to encourage farmers to relinquish certain plots of landfields to concentrate on those which are more resilient. A necessary additional requirement will be the design of different types of adapted insurance intended for farmers, which will gradually replace compensatory funds. Public reinsurance



Grounded boat near Mo'ynoq, a former port located south of the Aral Sea, in Central Asia. This saltwater lake has dried up partly because the rivers that fed it were used for irrigation.

plans will be necessary, given the costs involved.

It should be noted that adaptation to drought is often achieved through usage restrictions. These need to be applied uniformly for a given geographic or administrative area, differentiated by the type of use - residential use taking priority. Finally, we can consider a last example for adaptation: concerted water management at local levels, more often than not by collective groups of farmers. Based on designated rules for resource sharing which are decided collectively, these systems are often more widely accepted than pricing initiatives, but they would not be sustainable without water.

These collaborative efforts are not restricted to extreme situations. Sustainable adaptation requires a territorial vision of resources and water needs. This approach calls for the approval of all actors involved and applies to different problems: drinking water supplies,

agriculture, industry, energy restrictions and ecosystem preservation.

The watershed - an area where all waters converge to one common outlet - is the zone naturally best suited to this collective reflection. In this context, it should be given priority for the use of soils that have the highest capacity for adaptation and resilience. This approach will lead to the development of management tools able to integrate agricultural and hydrological considerations at different levels.

Considering that water as a resource may generate conflicts (see details on the opposite page) these adaptations will need to integrate the concept of equity between concerned actors. Watershed management will require responsible engagement with neighboring basins, keeping in mind that adjustments can impact not only local systems but can have large-scale reaching effects on river, coastal and marine ecosystems.

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